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A Chip off the Old Rock: An Investigation of Hunter-Gatherer Lithic Behavior at Site 48PA551 Using the FIeld Processing Model

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A CHIP OFF THE OLD ROCK: AN INVESTIGATION OF HUNTER-GATHERER LITHIC BEHAVIOR AT SITE 48PA551 USING THE FIELD PROCESSING MODEL

By

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ABSTRACT

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A Chip off The Old Rock: An Investigation of Hunter-Gatherer Lithic Behavior at Site 48PA551 Using the Field Processing Model

Chairperson: Dr. Anna Marie Prentiss

This research examines the lithic and raw material assemblage at site 48PA551, a McKean complex hunter-gatherer site in northwest Wyoming, through a lens of human behavioral ecology, central place foraging theory, and the field processing model. The identification of lithic technological patterns through this theoretical framework results in understanding the relationship between the landscape, hunter-gatherer behavior, and raw material procurement strategies in the region 4500 BP. The goal of this research is to identify economic decision making in reference to management of toolstone within the lithic assemblage uncovered at site 48PA551 during the 2018 field season. The expectation put forth by the field processing model is if there is a greater distance between the quarry and the central place a person is more likely to partake in field processing in order to acquire the most optimal load to transport. Debitage were analyzed by sorting material types by stages of reduction with the expectation that if field processing would lead to an absence of early stage reduction flakes at the central place. Supplementary, the tool assemblage was investigated for signs of tool investment attributed to long material transport distance. The outcome of this research suggests that there is a relationship between the assemblage and lithic transport decision making for many material types in the region, but a few material types indicate involvement of other cultural processes.

Chapter 1: Introduction

Introduction

Site 48PA551 has proven to be both scientifically and culturally significant due to its great potential contribution toward understanding Northwestern Plains socio-economic strategies of the McKean Complex associated with the Middle Archaic period. The site was first excavated in 1969, a project led by the Wyoming Archaeological Society (WAS). Through analysis of the uncovered features and artifacts, archaeologists interpreted the site to be a winter seasonal residential camp with evidence of long-term occupation. Radiocarbon dating indicated the site was 4000 to 5000 years old (Frison and Walker 1984). This provided archaeologists with the hope that site 48PA551 would help identify patterns of adaptive behavior in the Sunlight Basin during that time (Larson and Francis 1997).

Because of its significance in understanding the cultural timeline of the region, site 48PA551 was placed on the National Register of Historic Places in the early 1970s for the purpose of preservation. However, its listing could not protect it from looters and erosion into the Dead Indian Creek. This prompted a partnership between the University of Montana and the USDA Forest Service, Shoshone National Forest beginning in 2017 in order to perform data recovery and cut bank restoration in an effort to prevent further information loss (Prentiss et al 2017). Activities performed during this collaboration included test excavations, magnetometry, ground-penetrating radar, and laboratory analysis. The findings from the field excavation and laboratory analysis included the discovery of two new possible pit houses, numerous pit features, and significant numbers of lithic artifacts and faunal remains (Prentiss 2019).

The results from the most recent project have provided opportunities for in-depth and focused research including this study. The goal of this research is to use site 48PA551's lithic assemblage to understand the relationship between the landscape, hunter-gatherer behavior, and raw material procurement strategies of people in the Sunlight Basin during the McKean Complex. By using a theoretical lens of human behavioral ecology, this research helps identify lithic technological patterns to explain decision making and answer questions such as: what can be learned about the behavior of hunter-gatherers in the Sunlight Basin during the Middle Archaic through analysis of the lithic assemblage? Was this behavior economical? How does past technological behavior help archaeologists understand the relationship between people and their landscape?

This analysis consists of examining the assemblage uncovered in numerous test units during the 2018 field excavation at site 48PA551. The assemblage is made up of both debitage and stone tools with an impressive representation of different raw material types including chert, obsidian, and chalcedony. Through a lens of Human Behavioral Ecology (HBE) and Central Place Foraging Theory the assemblage will be used to model the acquisition, transport, and use of different material types based on transportation time and distance (Beck et al. 2002; Bettinger 2009; Smith 2000). The field processing model will be tested using the Flenniken lithic reduction stages and tool maintenance analysis (Andrefsky 2009; Beck 2008; Binford 1979; Clarkson and Bellas 2014; Flenniken 2001).

This research is valuable in a number of ways. The identification of chert, chalcedony, quartzite and other raw materials will not only help answer questions about the past occupants of site 48PA551, but for an entire region of archaeological sites. It will also make an impact because the site has yet to be interpreted through a theoretical lens despite the fact that it has been revisited several times. By implementing concepts from Human Behavioral Ecology and evolutionary archaeology, it will be the first step in understanding this site at a deeper level. Further, it will help researchers understand the evolution of the Rocky Mountain hunter-gatherer socio-economic strategies.

Outline

This thesis is organized into six chapters. Chapter two begins with the background of the site. By summarizing the archaeological record of the Sunlight Basin region, as well as providing a cultural background, this information provides valuable research context. Uniquely, site 48PA551 has been the subject of several archaeological research projects, therefore a brief history of the findings and history of archaeological involvement at the site has been included. Also, this chapter will provide context and review terms related to lithic analysis, as well as provide a glance of the lithic assemblage from site 48PA551.

Chapter three is a description of the theoretical lens. It begins by discussing evolutionary archaeology and Human Behavioral Ecology (HBE). This discussion provides the framework for central place foraging theory, which will be used to explain hunter-gatherer foraging strategies and behavior. Together, these theories are used as a basis for the hypotheses and expectations tested in this study.

Chapter four is an overview of research methods and includes a brief explanation of field and laboratory techniques. It will also briefly discuss the use of Flenniken's Lithic

Reduction Stages, the field processing model, and the use of Geographical Information System (GIS) tools. Chapter five presents the data analysis. A critical examination of data is necessary to analyze trends, form conclusions, and discuss results related to the hypotheses. Limitations of the data and methods will also be detailed. Chapter six will end with the final discussion and conclusions of the study. It will also provide suggestions for future research.

Chapter 2: Background

The Absaroka Mountains in Northwest Wyoming have been home to people for thousands of years. Today this area holds the evidence of their occupation at numerous significant archaeological sites that are rich with academic and cultural value. Some of the most well-known sites include Mummy Cave, Helen Lookingbill, and Caldwell Creek, all of which have contributed to the narrative of this region's past (Kornfeld 2001; Scheiber 2013; Wedel 1968). Greater Yellowstone Area research has also greatly contributed to knowledge of the region as a while (Adams and MacDonald 2015; MacDonald 2018; MacDonald and Nelson 2019, MacDonald, Horton, Surovell 2019). Even more is expected to be discovered with increased focus on high alpine archaeological survey in the area (Todd 2015). This study strives to contribute to the historical narrative of this region.

The goal of this chapter is to provide a regional description and historical overview of the Absaroka Mountains and the Sunlight Basin region and discuss previous archaeological work completed at site 48PA551. Additionally, this chapter will discuss lithic terms and logic while offering an overview of the lithic assemblage uncovered during the 2018 field season.

Regional Overview

Site 48PA551 is located in the foothills of the Absaroka Mountains in the Sunlight Basin area. At an elevation of roughly 6000 feet, the site sits on a river terrace along the Dead Indian Creek. It is surrounded by moderately dense forest and steep slopes of exposed limestone which protect the area from the elements (Frison and Walker 1984). The Absaroka Mountains are the result of volcanic activity and are comprised of older sedimentary rocks and extrusive igneous rocks formed during the last volcanic event estimated to have occurred 50 million years ago (Antweiler 1979; Heasler et al. 1996). This means that people living in the region could have had access to a diverse amount of lithic raw material resources such as chert, chalcedony, and obsidian. The region is also webbed with streams and rivers such as the Dead Indian Creek that are fed by snowmelt and glacial runoff at high altitudes (Heasler et al. 1996). The streams in turn maintain the Sunlight Basin ecosystems and provide for a diverse number of plant and animal species. The meadows, grasslands, and conifer forests of the region are the natural habitat for many large mammal species such as elk, mule deer, moose, and bear (Buskirk 2016). The Sunlight Basin has also cultivated numerous edible plants that produce tubers, seeds, fruits, and nuts. Some of the most common include black currant, biscuitroot, and spring beauty (Dolinar 2019). Observations supported by the archaeological record indicate these readily available resources of lithic raw material, food, and fresh water all reasons why the region was attractive to ancient hunter-gatherers.

For thousands of years, the Sunlight Basin acted as a travel corridor connecting the Bighorn Basin in Wyoming to the plains of Montana (Scheiber and Burtt 2014). An extensive archaeological record illustrates human occupation over thousands of years taking advantage of the rich natural resources of the region (Frison et al. 1986). Although it is likely the area was used by people from several different cultural backgrounds, it is most noted for being associated with tribal nations including, but not limited to, the Eastern Shoshone and the Crow (Larson and Francis 1997; Wood 1998).

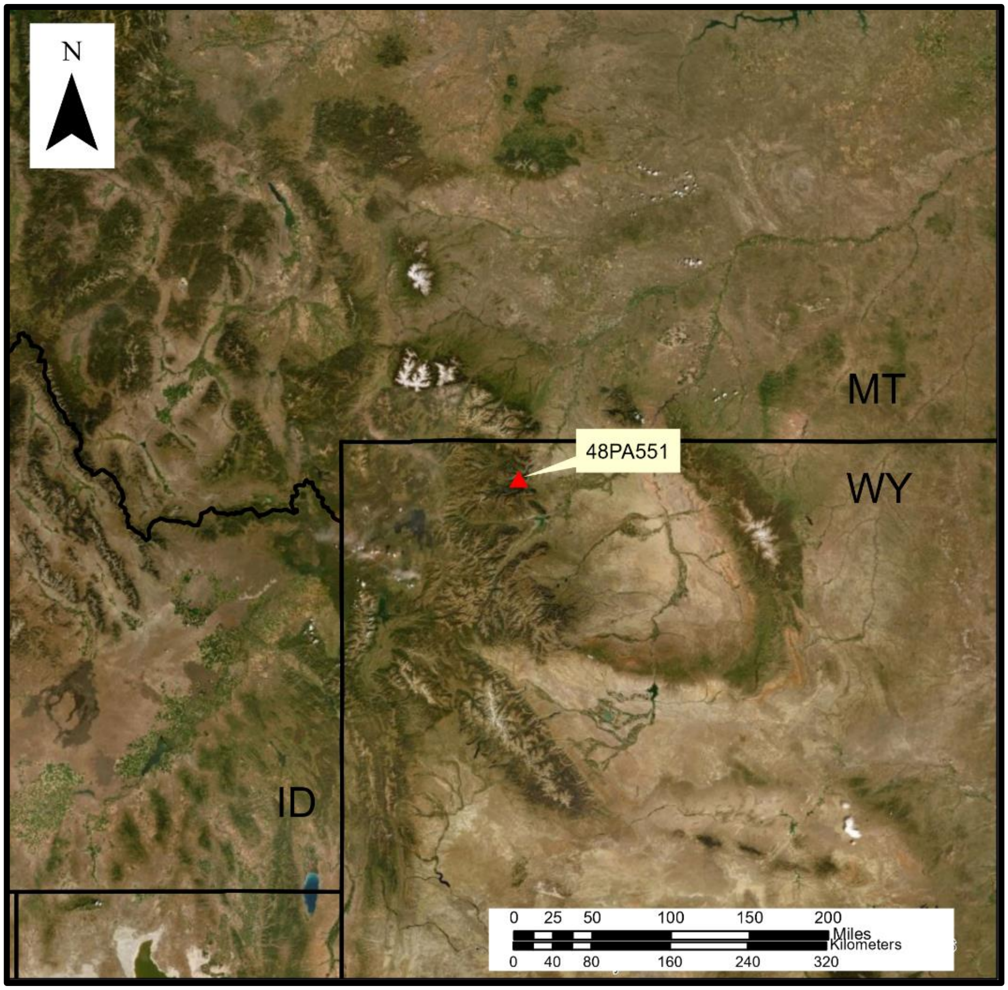

Figure 1. Map of Northwest Wyoming with location of Site 48PA551.

Sunlight Basin Historical Narrative

The Sunlight Basin historical narrative has been learned through a combination of archaeological investigation and shared oral traditions from tribal nations (Shimkin 1947). Before miners and fur trappers first visited in the 1800s, the region had been home to communities for thousands of years (Frison and Walker 1984). In fact, evidence has shown proof of consistent occupation as early as the Paleoindian Era with sites dating back as early as 9000 years BP (Wedel 1968).

The Late Prehistoric era dated from roughly 2,000 BP to European contact to about 200 years ago (Davis and Reeves 1990) and is characterized by a time in which the region was utilized by complex hunter-gatherer groups (Bamforth 1988; Cooper 2008; Zedeno et al. 2014). These groups are believed to be the ancient ancestors of present-day tribal nations. The cultural climate included organized communal mass harvest and great focus on large mammal processing (Prentiss 2019). It was also a time of logistical and residential mobility, making tipis the structure of choice (Kelly 1983). They also were greatly invested in the acquisition of lithic raw material through trade and quarry site procurement (Francis 1983; Prentiss 2019).

The Late Archaic saw many of the same behaviors as the Late Prehistoric. Socio-economic strategies such as hunting and processing large mammals occurred (Prentiss 2019). In fact, many of the behaviors observed in the Late Prehistoric were developed from socio-economic strategies that originated in the Archaic Period. Specifically, the archaeological record shows the Late Archaic people also practiced communal hunting, mobility, and intensive lithic procurement; but the technological advancements of the Late Prehistoric allowed for greater efficiency and frequency (Reeves 1990). People during the Middle and Early Archaic lived in smaller camps, periodically used large pit features including pit houses, and also practiced intensive hunting and harvesting of plants (Prentiss 2019). Tool diversity is also common at sites from this period including groundstone, scrapers, knives, and projectile points (Kornfeld et al 2010).

Evidence from site 48PA551 indicates there were multiple occupations over time. The most prominent occupation is during the Middle Archaic and is the focus of this research

(Frison and Walker 1984). The site also confirms evidence of a Late Prehistoric and possibly an Early Archaic occupation (Frison and Walker 1984).

Archaeological History of 48PA551

Site 48PA551 was first identified by avocational archaeologists in 1967. Since then, it has been investigated several times, most famously by George C. Frison in the early 70s (Frison and Walker 1984). The most recent visit was in 2018 by Anna Prentiss (Prentiss 2019). Excavations at the site began in 1969 and were led by the Wyoming Archaeological Society (WAS) continuing through 1972. Multiple excavation units were opened in many locations along the western extent of the site close to the bank of the Dead Indian Creek. During this time, the site was mapped for the first time and a variety of artifacts and features were uncovered (United States of America Department of the Interior, National Park Service 1973).

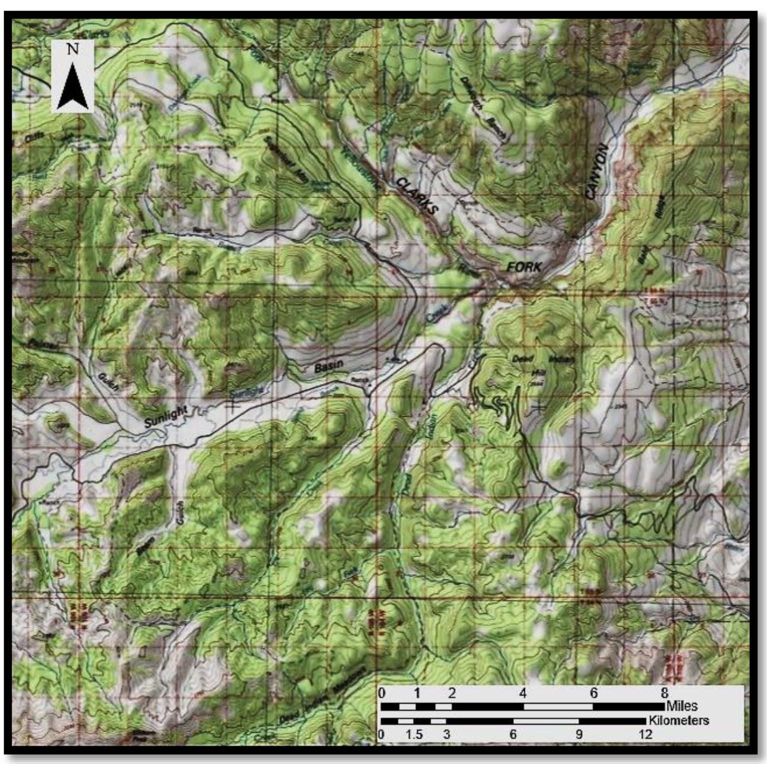

Figure 2. Topographic map of the Sunlight Basin.

The artifacts recovered from the 1970s excavation included “566 projectile points and point fragments, 259 other chipped stone tools, 55 ground stone tools, and a diverse assortment of bone tools” (Prentiss 2019: 4). The faunal remains of numerous different species were also uncovered, though the assemblage largely consisted of mule deer bone and bone fragments. The excavations also uncovered multiple hearth features and evidence of a Late Prehistoric occupation including a tipi ring and horse bones. The site gained attention with the unearthing of two major features; the first being a possible pit house associated with an arrangement of mule deer skull caps with antlers, and the second, a young child burial. The academic and cultural value of this site became obvious with these discoveries. Site 48PA551 was initially believed to be a butchering site, but with the discovery of these unique features its potential expanded to a place of habitation, food processing, mortuary practice, and ceremonial and ritualistic behavior (Frison and Walker 1984; Prentiss 2019). During this excavation, three radiocarbon dates were taken spanning from 3800 +/- 110 to 4430 +/- 250 BP, indicating the site was occupied during the Middle Archaic Period.

Minor excavation in compliance with the National Historic Preservation Act (NHPA) and the Department of Transportation Act occurred in 1985 and 1989. In 1985 test units were dug in association with the Clark Fork road and bridge reconstruction and maintenance project. The excavation occurred far from the original excavation area, but the discovery of additional cultural material provided the first indication of the enormity of the site. A single radiocarbon date was taken dating the new cultural material to 5470 +/- 130 BP suggesting that the site was even older than originally thought. It was now possible that there was an Early Archaic occupation (United States of America Department of the Interior, National Park Service

1973). In 1989 a single test unit was excavated during a maintenance project at a nearby campground, though no new cultural material was found.

The most recent research at the site occurred in 2017 and 2018 by Dr. Anna Prentiss and her University of Montana based team. Prentiss was approached by the Shoshone National Forest to identify new cultural features, assess the loss of cultural material to ongoing erosion, reinforce the cut bank to prevent further information loss, and collect at-risk data (Prentiss et al. 2017:2). The 2017 field season work included topographic mapping, geophysical analysis, and site loss assessment. Many subsurface anomalies were identified and were selected for further investigation in future field seasons. In 2018, test excavations were conducted throughout the site to assess locations of interests; at the cut bank and at locations of identified anomalies through magnetometry and ground penetrating radar (GPR). The test excavations uncovered many features including two house pits.

Lithic Analysis Overview

Lithic analysis is the study of stone artifacts including bifaces, unifaces, ground stone tools, projectile points, and debitage. Lithics are often the most common artifacts uncovered at many prehistoric sites, and archaeologists rely heavily on them to answer questions about human behaviors and lifestyles in the past (Andrefsky 2001; Odell 2014). Stone tools and debitage provide insight into many aspects of what it meant to be a human during these time periods (Andrefsky 2005). This study uses lithic analysis to understand procurement strategy and human landscape relationships, but lithics can also be used to discover other socio-economic strategies used by past groups. Tool production, subsistence strategies, trade, and mobility are just a few examples of topics studied using lithic assemblages. Lithic analysis has also been used to understand site formation processes (Binford 1979). This study investigates the relationship between attributes of the lithic assemblage and use of specific material types at site 48PA551. This is done by identifying the stages of reduction within the debitage assemblage, recording patterns of stone tool retouch and examining how they are related or unrelated to the characteristic of raw material (Andrefsky 2008; Flenniken 1981, 2001). The following section reviews key lithic analysis terms and logic that will be used in the following chapters.

Debitage is the byproduct of chipped stone tool production (Andrefsky 2001). The production process can involve multiple stages of removal through different knapping strategies: hard percussion, soft percussion, and pressure flaking. Each method produces distinctively different looking debitage. The tool manufacturer also chooses the flaking method based on the stage of tool production. For example, hard percussion flaking is typically an early stage method which removes larger, more robust flakes, while pressure flaking is a late stage method removing smaller size flakes in a more controlled manner. Each stage of tool reduction leaves different distinctive flake characteristics which are later identified by archaeologists. The key attributes being investigated include striking platform, lake size, cortex, and flake type (Andrefsky 2005).

The striking platform is the location on the flake where force was applied during the flint knapping process (Hayden and Hutchings 1989). There are three types of fracture initiation created at these striking platforms; cone, bending, and wedging (see Figure 3) (Odell 2003). Cone initiation is identified by the Hertzian cone-like fracture and fan-shaped percussion ripples through the flake starting at the striking platform (Andrefsky 2005). Bending initiation is identified by a distinctive lip at the point of impact. This initiation is often the result of applying force to a relatively narrow angled edge (Andrefsky 2005). Wedging initiation is the result of compression fracturing and is identified by a relatively flat fracture surface (Cotterell and Kamminga 1987). Many bipolar cores show the signs of wedge fracture initiation. It is important to identify the striking platform and the fracture initiation because it can be informative about the reduction stage, as well as, lead to the identification of flake type (Flenniken 2001).

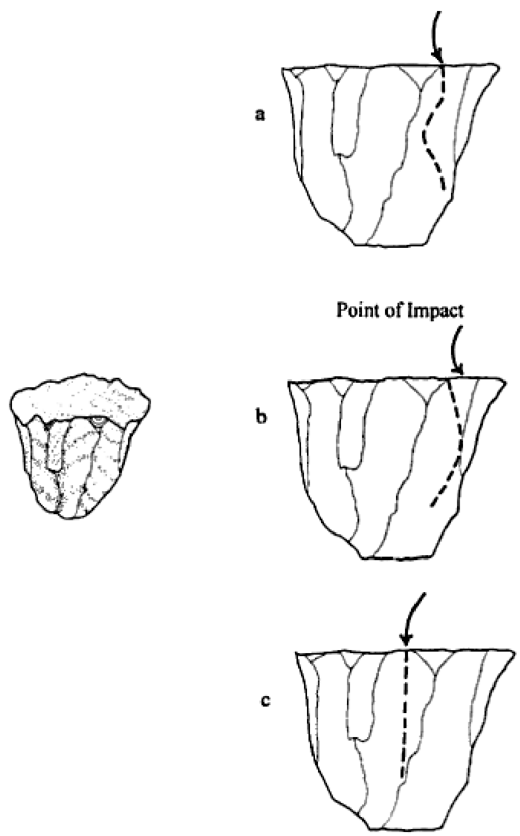

Figure 3. Diagram of three types of fracture initiation: a) Cone, b) Bending, c) Wedge. (Andrefsky 2005:27).

Flake size is also measured during debitage analysis (see Figure 4). It is important because flake size is an indicator of what point a flake was removed during the tool making process. For example, early stage reduction flakes are larger in size while final stages of reduction are typically performed by pressure flaking resulting in smaller flake size (Bradley and Fulford 1980). Cortex is the surface of the stone which has been exposed to the elements giving it a weathered appearance and texture (Andrefsky 2001). The cortex is often considered to be a low utility part of a stone and rarely used for tools, therefore it is removed in the early stages of tool production (Mauldin and Amick 1989).

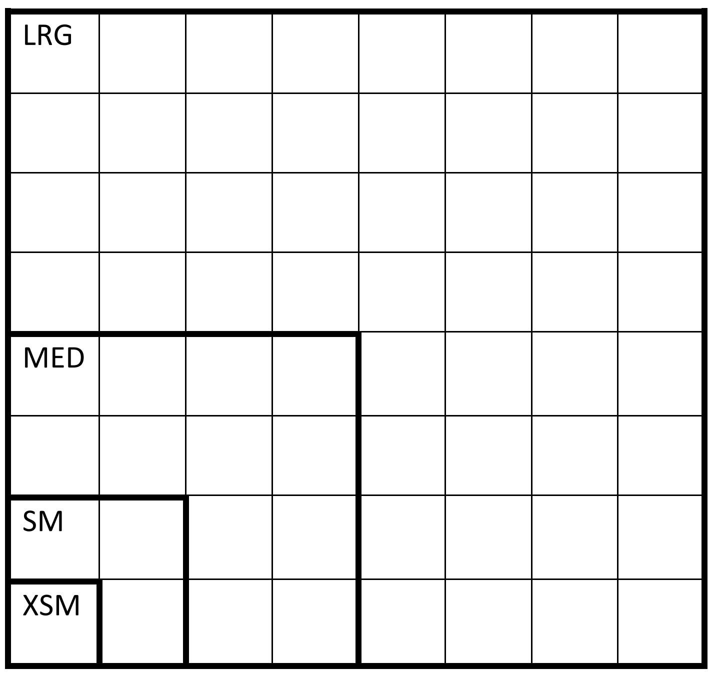

Figure 4. Flake size classes. Each grid square is 1cm x 1cm. Flakes greater than $64cm^2$ are XLRG

Flake type is a classification which takes into account all the attributes previously discussed. Types such as early-stage reduction, thinning, and retouch flakes are determined by an archaeologist based on which attributes are visible during analysis. However, a single attribute cannot determine the flake type or stage of removal on its own, but when multiple characteristics are available, a piece of debitage becomes more easily typed. Unfortunately, debitage is not always found by archaeologists in perfect condition and diagnostic characteristics are frequently lost. The flakes have either been trampled, intentionally broken, or worn by the elements. Breakage can also occur during the removal process. These flake fragments are then called medial-distal or non-orientable flakes and attributes such as flake size and fracture initiation are lost. This is the reality of archaeology. This leads archaeologists to record the level of completeness of flakes during their analysis, listing them as either complete, split, proximal, or medial-distal (Sullivan and Rozen 1985).

A site lithic assemblage can be highly variable. Although they are typically not as frequent as debitage, stone tools provide a vast amount of information about past human behavior including pattern of technology, tool morphology, raw material selection, and the function (Odell 2014). Technology involves how the tool was manufactured. For example, stone tools can be separated into three major groups; bifacial, unifacial, and ground stone. A bifacial tool has been retouched on both sides of an edge angle creating a point similar to a steak knife. Alternatively, a unifacial tool has been retouched on a single side of an edge creating a point similarly to a scalpel. Ground stone tools are not created through the process of chipping, but instead are used to make abrasions or are being abraded against; examples include pestles and mortars. Tool morphology primarily concerns tool shape, which can be measured in a number of ways resulting in quantitative data. These data include height, width, thickness, weight, and volume.

The function of a tool can be determined by use wear. Use wear often presents on stone tools in the form of; striations, chipping, rounding, polishing, abrasion, crushing, grinding, and countless more. These use wear attributes are valuable in understanding the tasks performed by people and how the tool was used. It is also valuable to recognize when a tool has multiple uses and when it has been retouched or sharpened. Investment in maintenance would be valuable to a prehistoric hunter-gatherer because it would extend the use life of their tools (Andrefsky 2008). Signs of lengthy use-history include smaller than average tool size compared to thickness due to intensive retouch, and more than one type of used wear indicating that a tool had multiple uses, and lack of expedient tools such as used flakes and more formal tools like projectile points (Barros 2015; Esdale 2009). Finally, the raw material of stone tools is valuable information when understanding the behaviors of the people of the past. This can be done by comparing the raw material's source location to the location where the assemblage was uncovered. If the raw material is from a source a great distance away it is considered to be exotic. From exotic raw material it is possible to infer use of trade, logistical mobility, or increased perceived value of the raw material (Odell 2014). Often while investigating material types archaeologists will look at the presence or absence of heat treatment. Heat treatment of stone in the process of manufacturing tools is an interesting method and can tell researchers about practices and technological innovations (Domanski and Webb 1992).

The 2018 excavations at site 48PA551 resulted in the uncovering of approximately 6000 pieces of debitage and over 100 stone tools. This expansive lithic assemblage was analyzed in a lab at the University of Montana where a typology was established. The tool typology was created with regional tool types in mind (Kornfeld et al 2010; Scott and Zeimens 1984). The attributes of interest within the stone tool assemblage included: raw material type, thermal alteration, tool size, retouch types, use wear types, and tool type. The debitage was analyzed with criteria including; raw material type, thermal alteration, size, cortex, completeness, fracture initiation, and flake type. This process will be explained in more depth in the methods section of this report. The raw material types at the site have proven to be very diverse and include a range of chert and chalcedony. Other highly abundant types within the assemblage include obsidian, quartzite, limestone and basalt.

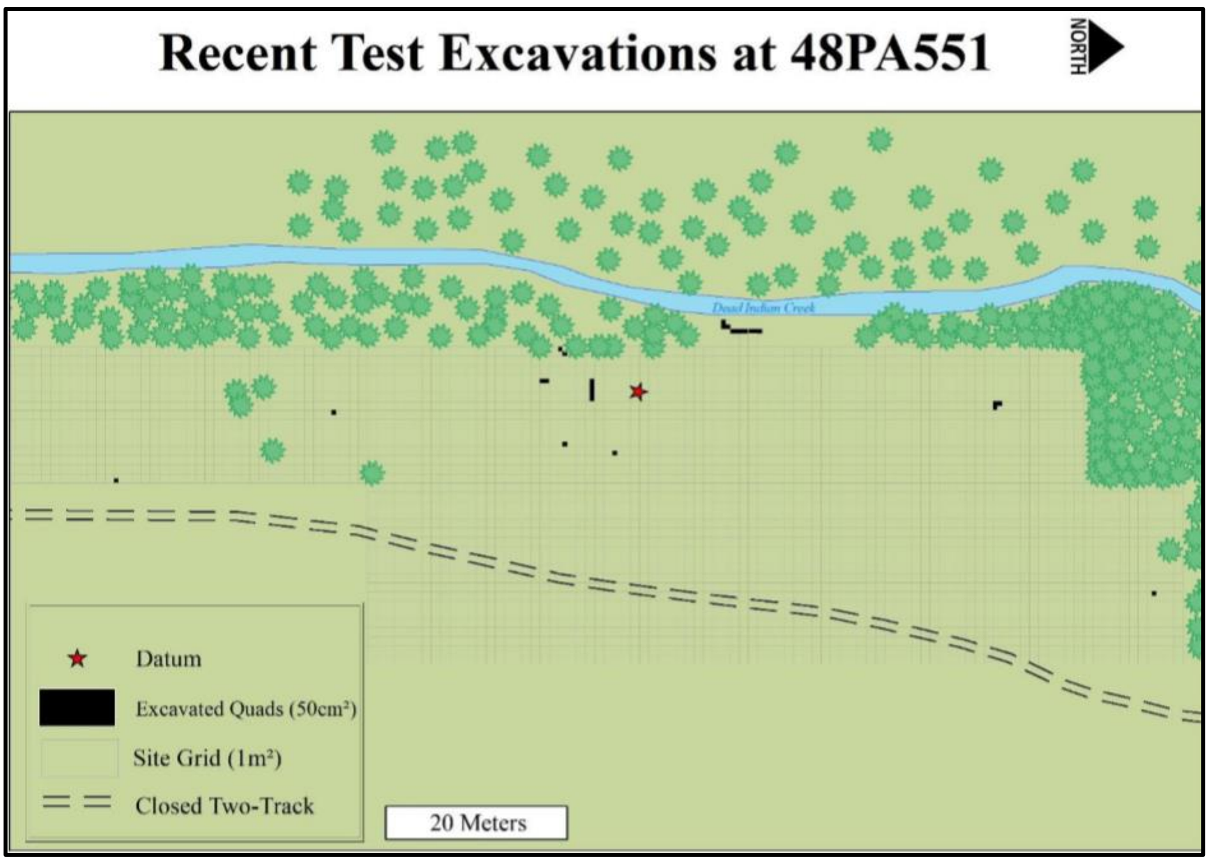

Figure 5. Grid map of Site 48PA551 indicating locations of 2018 field season excavation units (Prentiss 2019;14).

Many chipped stone tools were identified in the 2018 assemblage including scrapers, bifaces, unifaces, utilized flakes, and projectile points. The ground stone tools included manos, abraders, and a metate. The presence of these tools suggests that hunting game and processing meat were important tasks at the site during the Middle and Late Archaic occupation (Prentiss 2019). The small representation of ground stone in contrast to chipped stone tools may suggest that there was a greater investment in hunting than in plant processing. The diversity of raw material also suggests that the occupant of site 48PA551 traveled and could have gathered their raw mineral resources from quarries as far away as the Bighorn or Pryor Mountains (Prentiss 2019).

Chapter 3: Theory

This study is an examination of site 48PA551's lithic assemblage through a theoretical lens of evolutionary archaeology and human behavioral ecology. This chapter explains these theoretical concepts and dives deeper into hunter gatherer behavior. This is accomplished through the use of central place foraging theory and the field processing model. This chapter also describes how lithic procurement strategies can be investigated through these frameworks and ideas of site formation processes. Finally, there is a presentation of the hypotheses driving this study.

Theory

Evolutionary archaeology is the theoretical background of this study. It is driven by the belief that Darwin's theories of natural selection act upon human behaviors to mold culture over time and thus can be identified within the archaeological record (Teltser 1994). Evolutionary archaeology is also the process of examining "historical patterns of differential trait representation" and explaining how "evolutionary [processes] acted to create those patterns (Jones et al. 1995:29). It has led to investigations involving concepts such as lineage, natural selection, transmission mechanisms, innovation, diffusion, and heritability (Lyman and O'Brien 1998). Most importantly to this research project, Darwin's theories have contributed to the understanding of adaptation of behaviors in connection to one's environment (Smith and Winterhalder 1992). This direction is known as human behavioral ecology (HBE).

HBE strives to apply Darwin's theories of evolution and fitness to human behavior and how that behavior shapes society and culture (Kelly 2007). Fitness in HBE is explained as the optimization of behaviors leading to an increase in one's reproductive success resulting in the survival and transmission of traits and behaviors (O'Brien and Lyman 2003). HBE also evaluates how socioeconomic factors influence human behavior and show differences in behaviors result in cultural variation between groups of people (Smith and Winterhalder 1992). These socioeconomic factors are largely impacted by the environment causing variation in culture based on availability of resources and the optimization of procurement time (Kelly 2007). This suggests a strong relationship between human behavior and the natural and manufactured environment (Surovell 2012).

In short, HBE is the study of how people problem solve in their everyday lives within their environments (Surovell 2012). Although HBE can be used to understand a variety of cultures in a multitude of different environments, this study uses it to investigate hunter gatherer behavior from the McKean Complex in the Sunlight Basin. With this focus, models derived from HBE can help explain activities such as food capture, mobility patterns, and resource procurement. This research focuses upon behaviors involving the acquisition and transportation of lithic raw materials. This study recognizes optimization and efficiency of this resource transport in a few key ways; speed of transport, quantity within a load, and the utility of a load. It is theoretically possible to see evidence of this optimization in the archaeological record and can be best modeled through central place foraging theory and the field processing model.

In order to best understand the reasoning behind central place foraging theory, it is crucial to first understand and recognize the hunter-gatherer strategies of residential and logistical mobility. Residential mobility is the practice of relocating the central place (or residential base) when the surrounding resources have been depleted (Binford 1980). Conversely, logistical mobility involves travel to resource procurement sites that are too far away from the central place to return within the same day (Binford 1980). Both residential and logistical mobility work under the assumption that a forager will return all collected resources to the central place. This is the cornerstone of central place foraging theory because the foraging models are built on the concept that resources are acquired and then transported back to the central residential site (Beck et al. 2002). This theory works under the assumption that humans behave in an economically rational and predictable way to increase their fitness. It also explores the choices made by people in the past to maximize the rate of foraging by optimizing transport time, size of load, and utility of the load. Then, inferences can be made about how optimization is reflected in the archaeological record uncovered at a central place (Bettinger 2009).

The field processing model falls under central place foraging theory. It strives to predict trends of perceived optimized behavior related to resource procurement and transport (Beck 2008). It is used as a tool to make assumptions about how optimized behavior is visible within the archaeological record and leads to interpretations about people in the past. It is also used to form testable and quantitative predictions about whether these people practiced economic decision making (Metcalfe and Barlow 1992). Bettinger (2009) describes the field processing model as the central place foraging problem of how to maximize the rate of transporting resources from a procurement site to the central place while limited by load size. It explores the balance between processing a load to increases utility and the time of transport. Its purpose is to increase the utility of the load by removing low utility material such as cortex

(Metcalfe and Barlow 1992). Field processing modeling is established on the idea that if the time traveled between the procurement site and the central place is limited, making the trip with unprocessed materials would be more efficient because a return trip is short. If the time traveled is long and frequent visits to the procurement site are impractical, processing the material to increase the load utility would be the more efficient choice. The model proposes that the longer the travel time, the more processing will occur in the field. Thus, evidence of early stages of processing will be absent from the artifact assemblage uncovered at the central place (Beck et al. 2002; Beck 2008).

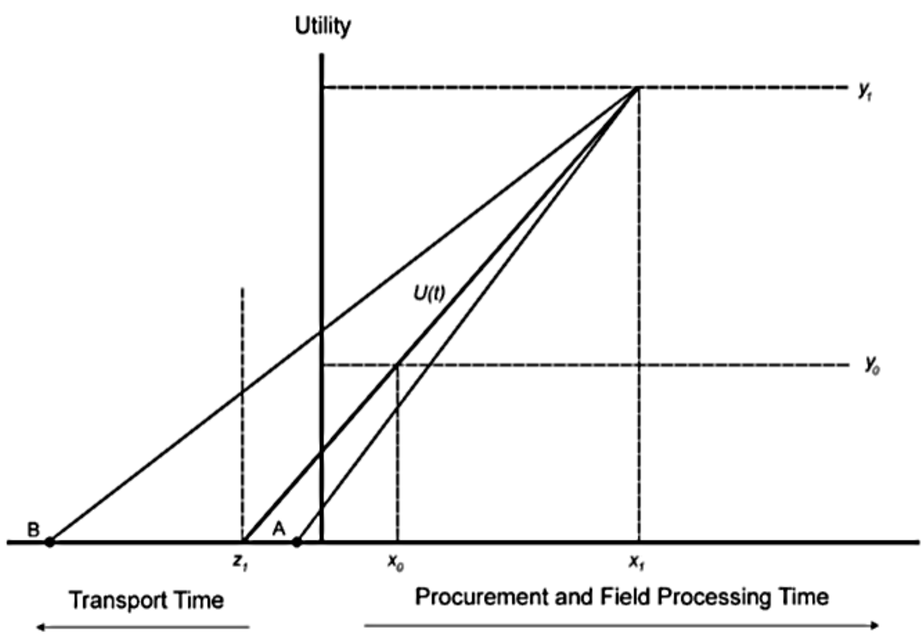

Figure 6. Model showing the relationship between field processing and utility. Increase in field processing time, X_0 to X_1, increases material utility, Y_0 to Y_1. The slope predicts the travel time necessary to make field processing cost-effective. (Beck et al. 2002:487).

Metcalfe and Barlow (1992) determined the field processing model is dependent on a few underlying assumptions; the procurement site and central place are not the same locations, the forager has the means to procure and transport the resource to the central place, the forager's goal is to bring the resource home to use it, and the forager will make strictly economic decisions. Further, it is assumed that the goal of the forager is to optimize the acquisition and transport of the resource when considering field processing because processing at the central place is less time consuming and costly, there is no time limit for the forager to field process or transport the resource, and finally, the most optimal load size is dependent on and less than the total amount of resources available (Metcalfe and Barlow 1992:344-345).

Archaeologists have been answering questions about the relationship between human behavior and hunter-gatherer lithic procurement strategies within their own study areas for decades (Beck et al 2002; Brantingham 2003; Church 1990; Gould 1968; Hocking 2013). Many have also valued the idea of locating procurement sites and sourcing raw material if they were not yet known (Knight 1989; Magnin 2015; Wilson 2007; Williams-Thorpe 1997). Research of this kind requires lithic assemblage analysis and the understanding of site formation processes and middle-range theory.

Site formation processes are the natural and cultural actors responsible for the archaeological record as we see it today (Schiffer 1972). These processes can be anything from rodent burrowing and erosion to cultural processes like ritualistic dwelling burning or refuse removal (Binford 1979). Understanding how a site has developed over time, as well as, what behaviors have formed through the evolutionary process are important jobs for today's archaeologists as they excavate and uncover artifacts from sites. This research seeks to determine whether or not field processing occurred for specific lithic raw material types.

Site 48PA551's archaeological record was likely impacted by field processing given its potential effects on artifact representation. In concept, field processing is the process of removing low to no utility material from the load to be transported back to the central place. Processing allows for more space within the load for high utility material (Bettinger 2009). The model explains that the decision to partake in field processing is an economical choice influenced by the distance between a processing site and the central place. Humans practicing economic rationality choose to field process their acquired resources when it is optimal to do so. Early stage reduction flakes or low utility flakes would be absent from the central place archaeological record and instead would be present at the procurement site (Beck 2008). In theory, the absence of early stage reduction flakes and low utility flakes would suggest the practice of field processing for a material type while the presence would indicate that this behavior was not practiced.

Lithic analysis is valuable in research projects such as this because it can lead to the identification of different flake types and flake attributes. Many archaeologists have used experimentation studies to predict the reduction stages and typology of lithic flakes because they are exponentially more common than stone tools (Callahan 1979; Johnson 1981; Mauldin 1989; Shott 1994). Studies such as this one require lithic analysis on debitage to identify patterns of reduction stages for each material type uncovered at site 48PA551. By recognizing these patterns, it is possible to develop an understanding of the behavior of past occupants along with the use of the field processing model. Although there are many different approaches to identify reduction stages (Callahan 1979; Collins 1975; Odell 1996; Skinner 1990; True and Bouey 1990), this study uses J.J. Flenniken's (2001) reduction stages.

In his method, Flenniken determines at what point a flake is removed during the tool production process by analyzing the technologically diagnostic attributes of individual flakes (Beck 2008). According to Flenniken there are four separate stages that can be identified by assessing qualitative attributes (2001). Stage one is the first step in tool manufacture. Flakes removed during this stage are most recognizable based on characteristics including; presence of cortex, larger flake size, limited number of flakes scars, wedge fracture initiation and are often typed as early stage or bipolar reduction flakes (Flenniken 2001). Stage two debitage is typically typed as edge preparation flakes and are found to exhibit attributes such as; cone fracture initiation with a prominent bulb of percussion. They can also have the dimensions of an R-Billet flake, which is a triangular flake exhibiting a wide platform and short length with a triangular shaped cross-section. Stage three flakes are percussion thinning flakes and are characterized as thin with bend fracture initiation resulting from being removed from a thin edge of a tool. The final stage, stage four, is made up of flakes resulting from pressure flaking. These smaller flakes usually occur when the tool manufacturer. Flakes from this stage are often referred to as pressure reduction flakes or notching flakes.

By using lithic reduction stages, for example, drawing from the Flenniken method, an archaeologist has the ability to systematically organize and categorize debitage in order to better understand patterns of behavior related to stone tool manufacture. The assemblage can then be applied to models like the field processing model to test the applicability of the theory within the assemblage's cultural context.

The lithic assemblage uncovered at site 48PA551 in the 2018 field season is used to understand the relationship between the landscape, hunter-gatherer behavior, and raw materials procurement and transport strategies. The field processing model provides a guide to what high utility resource procurement looks like and can be used as a comparative tool to analyze the archaeological record (Bettinger 2009). This study tests the following two hypotheses in reference to several test expectations.

Hypotheses and Test Expectations

Hypothesis 1: The occupants of the Sunlight Basin during the Middle Archaic practiced economic rationality and therefore their behavior can be explained in light of the field processing model. With a focus on lithic technological behavior, it is possible to see optimal decision making related to raw material procurement and transportation. The field processing model helps determine that people made a rational decision on whether or not to process their acquired raw material in the field based on the travel time between the procurement site and the central place. This choice would result in the achievement of the most optimal load in relation to expenditure of energy and time.

This hypothesis asserts that when the distance to the procurement site is close to the central place and it is not practical to partake in field processing of the raw material, signs of early stage reduction will be present in the lithic assemblage at the central place. Characteristics of early stage reduction include high percentages of cortex, large flake size, and wedge fracture initiation (Ferris 2015). If the procurement site is far enough to favor the decision to engage in field processing in order to increase the optimality of the transported raw material, then the signs of early stage reduction in tool production will not be present at the central place. Use-life of toolstone will be extended by investment in maintenance and recycling and will likely be the goal of people who want to optimize the stone if transported over long distances. This would manifest in the lithic assemblage by having a higher representation of debitage removed during the late stages of reduction. This would include smaller than average tool size to thickness ratio, more than one type of use-wear on tools, and a lower percentage of utilized flakes (Barros et al. 2015; Esdale 2009). When raw materials are more readily accessible, the tool maker is less likely to expend the effort and energy to perform maintenance or retouch on a tool and more likely to discard an expended tool in favor for new material. Thus, the archaeological record will show patterns of expedient tools and little to no tool maintenance.

Hypothesis 2: Human behavioral ecology works under the assumption that humans behave economically and will make rational decisions when it comes to activities such as lithic raw material procurement. However, humans do not always make decisions based on this economical rationality and other cultural processes influence their behavior. Although it is hard to determine what cultural influences impact the act of lithic procurement, some examples include the practice of trade, belief in prestige and sacred material, and other seasonal nomadic patterns (Gould 1968).

This hypothesis expects that the distance to a procurement site does not predictably impact decisions related to degree of investment in field processing. Therefore, it is likely the presence of attributes within the central place assemblage such as high cortex percentage, greater flake size, and presence of early stage reduction flakes will not follow the patterns expected from the field processing model.

Chapter 4: Methods

This chapter provides a review of the methods used in the field and in the lab during this study. The most recent investigation of the site began in 2017 and has been worked on by Dr. Anna Prentiss, a team of graduate students, a crew of field school undergraduates, and many specialists contributing to the research with their expertise (Herzog et al. 2019; Prentiss 2019; Sheriff 2017; Todd and Reckin 2019).

Field Methods

In 2017, work at the site began with the establishment of a site grid and the relocation of the original site datum. Spatial data were recorded to assist with the development of updated site maps (Prentiss 2019). Magnetometry was also performed on the site to identify subsurface anomalies, guiding excavation unit placement in subsequent field seasons (Prentiss et al. 2017). In 2018, Ground Penetrating Radar (GPR) was performed at site 48PA551 as well. Both geophysical methods located subterranean anomalies and were systematically tested through test unit excavations.

Site 48PA551 was excavated in 2018 according to the following procedures. The test units were 50x50 centimeters in size and were placed on geophysical anomalies. They were excavated in 10 cm arbitrary levels while also following the natural and cultural stratigraphy of the site. This method allows for better control, allowing for more precise data collection and provenience when collecting and recording artifacts and features. Each level of soil excavated was collected and sifted through a 1/8 inch mesh screen. Artifacts found *in situ* and greater than 3 cm in length were bagged separately, recorded, and mapped individually on a unit form. Smaller artifacts and those found within the screen were collected in bulk bags separated by level and artifact type; lithic, faunal, FCR, and historic. Soil samples were collected from every unit and level with the intention to be used in a flotation study back in the lab, a process used to recover artifacts that are typically too small to be found in a sifting screen. Charcoal was also collected when encountered larger than the size of a quarter to be used for radiocarbon dating. The floor of each unit, the surface of features, and change in strata were mapped and photographed. Unit walls were chosen for profile maps and photographs based on their representation of features and distinct stratigraphic change.

Laboratory Methods

The lithic analysis of the materials collected during the 2018 field season continued through the fall of 2019. This analysis occurred in the Prentiss Archaeology Lab at the University of Montana. First all lithic material was cleaned. Debitage were then analyzed and classified by several attributes; material type and color, flake size (Prentiss 2001), fracture initiation (Hayden and Hutchings 1989), flake type, level of completeness (Sullivan and Rozen 1985), cortex coverage (Mauldin and Amick 1989), and presence of thermal alteration. Thermal alteration was determined in this project based on the presence of crazing, waxy appearance, and color change or reddening. For the specific purpose of this project, a greater focus was taken on the material type and color (see Table 1), flake size, cortex coverage and flake type. This is because these attributes either indicate specific raw material types from specific source sites or can be used to determine which stage of reduction the flake was removed from in the Flenniken method (Flenniken 2001). Site 48PA551 has a very diverse level of raw material and the typology was created with this in mind. As seen in Table 1, raw material classifications were not only determined by raw material type but also color and texture. The size classes were determined using a chart (see Figure 4) to sort debitage into five categories; extra small (<1cm^2), small (1-4cm^2), medium (4-16cm^2), large (16-64cm^2), and extra large (>64cm^2). After a flake was determined to have a Sullivan-Rozen completeness classification of complete, proximal, or split, its fracture initiation and flake type were established (Sullivan and Rozen, 1985). Fracture initiation was selected between three separate types; cone, bending, and wedge (Figure 3). The flakes were then sorted into technological types including; early stage reduction, thinning, R-Billet, retouch, bipolar, notching, and core rejuvenation flakes. If a flake was missing its platform it was given a Sullivan-Rozen classification of medial-distal (M/D) or non-orientable (N/O) and could not be typed. Cortex coverage was defined by the amount of a stone's original surface present on the dorsal side of a flake; primary (>90% coverage), secondary (1-90%), and tertiary (0%). The presence of thermal alteration was identified by characteristics such as crazing, way appearance, and color change or reddening. This data was recorded and entered into a debitage database.

Lithic tools are stone artifacts which show signs of retouch or use wear. The identified tools were separated from the debitage and analyzed with a different criterion. A tool typology for site 48PA551 was developed and was used to classify tool types based on tools regularly found in the region. Some tools have more than one working edge, and in order to organize the data each edge was labeled as a separate employable unit (EU) (Knudson 1983). Each EU

Table 1: RAW MATERIAL CODES FROM SITE 48PA551		
Material	**Code**	**Defining characteristics**
Chalcedony	1A	Clear/Milky, Translucent
	1B	Orange, translucent
	1C	Brown, translucent
	1D	Green, translucent
	1E	Marbled, Variation of Color, Translucent
Chert	2A	Green
	2B	Red
	2C	Orange to Yellow
	2D	Brown
	2E	Maroon to Purple
	2F	White
	2G	Grey
	2H	Marbled, Variation of Color
	2I	Black
Obsidian	3A	Black
	3B	Red
	3C	Black-Red Striped
Quartzite	4A	Grey, Fine-Grain
	4B	Grey, Coarse-Grain
Limestone	5	Red to Yellow
Basalt	6A	Black to Grey, Coarse-Grain
	6B	Black, Fine-Grain
Petrified Wood	9	Banded Brown
Sandstone	10	Tan/Beige, Coarse-Grain
Conglomerate	11	Mostly Grey, Many Inclusions
Steatite/Soapstone	12	Fine-Grain, Grey
Ochre	13	Orange to Red, Grainy and Crumbly
Granite	14	Grey, Granular
Shale	15	Black, fine-grain

was recorded separately. The attributes recorded for every tool included raw material type, thermal alteration, size, edge angle, retouch, and use wear. Size is a measurement of the length, width, and thickness and was acquired using standard calipers. Edge angle was measured by a goniometer. Retouch was assessed based on how far flake scars extended into the interior of the tool, abruptness of edge angle (invasive, abrupt, and semi-abrupt), and the type of flake removal (scalar, step, or hinge). Use wear was defined based on the presence of characteristics like polishing, rounding, striations (parallel, perpendicular, or oblique), chipping, crushing, pecking, grinding, notching, etc. Both retouch and use wear were examined through a 50x magnification microscope. The last step was to draw the tool to scale in both profile and plain view, providing detail for each EU.

Data Analysis

After the assemblage was sorted and the data were collected the information was analyzed through the following methods. The debitage were sorted into five different classes of lithic reduction identified by Flenniken (see Table 2) (Beck 2008). The first class is shatter. Shatter is characterized by the lack of diagnostic traits that can place a flake within one of the other classes. This happens when the platform of the flake broke off during the reduction process or due to natural processes such as trampling. Flakes are recognized as shatter if they are identified as medial-distal or non-orientable. These flakes cannot be used to determine which stage they were removed from a tool, and therefore cannot inform the level of processing for a material type (Flenniken 2001).

The four other classes correspond with Flenniken's stages of reduction. Stage one debitage are considered to be primary or early stage reduction flakes. They are the first flakes to be removed during the reduction process and can be typically identified by the following attributes; presence of cortex, larger flake size, few dorsal flake scars, and wedge fracture initiation (Flenniken 2001). Second stage reduction flakes are edge preparation flakes. They are characterized as being wider than they are long with a triangular cross-section, very similar

Table 2: Flenniken's Stages of Reduction (Compiled from Flenniken 2001)

Reduction Stage:	**Flake Types:**	**Description:**	**Diagnostic Attributes:**
Stage 1: Core Reduction	Primary decortication flake	Removal of cortex as the result of initial core reduction - **primary cortex coverage** on dorsal surface	-Presence of primary or secondary cortex coverage on dorsal surface. -Wedge fracture initiation -Larger flakes with few dorsal surface flake scars
	Secondary decortication flake	Later stages of cortex removal - **secondary cortex coverage** on dorsal surface	
	Early interior flake	Flakes from interior of parent stone, no cortex on dorsal surface, involved in early stage of flake blank production(large flake intended for reduction into tool)	
	Late interior flake	Flakes from interior of parent stone, no cortex on dorsal surface, last flakes removed from flake blank before bifacial thinning begins.	
	Bipolar flake	Compression flake, **wedge fracture initiation** and signs of crushing.	
Stage 2: Edge Preparation	Bulb removal flake	Percussion thinning flake which removes the platform and bulb of percussion from parent flake blank – **cone fracture initiation** and **bulb of percussion present** on ventral and dorsal surfaces	-Cone fracture initiation -Presence of bulb of percussion -Wide flakes with triangular profile
	Alternate flake	Percussion thinning flake resulting from creating bifacial edge on blank - flake is **wider than is long** with **triangular profile**	
	Edge Preparation flake	Flake removed from edge of blank to prepare for further edge reduction – flake is **wider than is long** with **triangular profile**.	
Stage 3: Percussion Bifacial Thinning	Margin Removal Flake	Flake removed from a thin edge producing **semicircular shape** and **bend fracture initiation.**	-Bend fracture initiation -Thin flakes with curved profile -Thin flakes with feather termination
	Early percussion bifacial thinning flake	Flake removed with purpose of increasing width-to-thickness ratio **–** few dorsal surface scars, **curved profile**, and multifaceted platforms.	
	Late percussion bifacial thinning flake	Flake removed in final stages of percussion reduction with purpose of increasing width-to-thickness ratio – many dorsal surface scars, flat profile, feather termination and multifaceted platforms.	
Stage 4: Pressure Bifacial Thinning	Early pressure bifacial reduction flake	First flakes removed during pressure reduction – irregular dorsal surface scarring, **small**, and platform forms an oblique angle	-Small fan shaped flakes
	Late pressure bifacial reduction flake	Flake removed in final stages of pressure reduction – **small flakes** with multifaceted platforms	
	Notch flake	Flake produces as result of creating a notch – **fan-shaped** and **small**	
Stage 0: Technologically Undiagnostic	Shatter	Irregularly shaped flake lacking diagnostic attributes	-Lack of platform or other diagnostic attributes
	Undiagnostic flake fragment	Flake lacking diagnostic attributes due to breakage or trampling	

R-billet flakes. They also can have a visible bulb of percussion and are typically formed through cone fracture initiation (Flenniken 2001). The third stage of reduction according to Flenniken is made up of debitage resulting from percussion removal creating thin flakes with a curved profile and bend fracture initiation (2001). Finally, stage four of the reduction process is made up of pressure removed debitage and results in flakes smaller in size with a fan-like shape (Flenniken 2001). Though Flenniken's method of identifying the stages of reduction in the lithic assemblage is very qualitatively descriptive, not all flakes can fall discretely in a single class. Some flakes have attributes that fall into more than one class and must be placed based on how many attributes the flake has in each stage. For example, if a flake has two attributes that would identify it as a stage two and one that would identify it as a stage three, it would more closely resemble a stage two and therefore fall within that category. Decisions about flake placement were also made when a shatter flake had primary flake attributes such as presence of cortex. This exception was made in this study because cortex is an attribute visible on a flake even if the platform is absent and is applicable to only one stage.

Tools were analyzed for signs of recycling, reuse, and maintenance. Smaller tool size to thickness ratio, more than one EU, and tool formality are all ways that maintenance can be measured on an individual tool (Esdale 2009). Patterns of material use within the assemblage were investigated by comparing the technological behavior of tools made from different material types to the predictions that a hunter-gatherer partook in the activity of field processing for material procured at non-local sources. These patterns include; greater percentage of exhausted tools or cores, fewer expedient tools, and smaller shaped tools will be more common (Barros, et al. 2015).

Chapter 5: Results and Analysis

This chapter provides an examination of the data by analyzing the trends and patterns within the site's lithic assemblage and how it relates to known source locations. The conclusions formed through the investigation are discussed related to the hypotheses. This chapter also evaluates the short comings and limitations of the data and methods used in the study.

Debitage Analysis

As stated in the previous chapter, the debitage uncovered during the 2018 field season was first analyzed using the typology established for site and was approved by Dr. Anna Prentiss. The assemblage was assessed for raw material, size, fracture initiation, flake type, completeness, cortex, and thermal alteration. The lithic material uncovered at site 48PA551 is diverse and includes multiple variations of color and texture, specifically within the chalcedony and chert material types (see Table 1). The diversity within specific material types is important to investigate because the variance may indicate acquisition from different source locations. This study manages the assemblage diversity by providing figures which display information in broad material groups and then provides a more in-depth analysis of the material distribution within the subcategories of the major raw material groups (chalcedony, chert, and quartzite).

Some research has been done in the region, specifically the Greater Yellowstone Area and the Absaroka Mountains to identify lithic source locations and discover how they relate to different pre-historic site assemblages (Church 1990; Reckin and Todd 2018; Reitze 2004). Not all material uncovered at site 48PA551 has been linked to a known source, but the ones that have can be seen in Table 3. While some raw materials uncovered at site 48PA551 resemble these sources, definitively linking them is difficult. Therefore, many of the designations made in this study are for heuristic purposes, especially for the chert, chalcedony, and quartzite material types. Limestone is known to exist in the cliffs above site 48PA551 while sandstone and conglomerate material are common and readily available throughout the region (Prentiss 2019). Basalt and coarse-grain quartzite have been found in streambeds of many rivers and creeks in the Sunlight Basin and the Greater Yellowstone Area which leads to the expectation that these materials are also available in the Dead Indian Creek, just west of the site. Petrified wood is believed to exist at high altitudes in the Absaroka Mountains and is a common material found at other prehistoric archaeological sites in the region, but the source is not readily known (Reckin and Todd 2020, Wilson 1965). One study sourced a sample of obsidian from site 48PA551 and determined that over 90% was procured and transported from two quarries in the Yellowstone area: Obsidian Cliff and Lava Creek Bluff (Reckin and Todd 2019). Cougar Pass is another obsidian source that exists in the Absaroka Mountains south of site 48PA551, though is known to be a poorer quality material than the Yellowstone quarries (Reckin 2018). Fine-grain quartzite derives from the Morrison Formation which has outcrops known to occur on the periphery of the Big Horn Basin (Prentiss 2019). South of site 48PA551, Dollar Mountain is a known source of chert, chalcedony, and quartzite, which consist of many color variations (Reitze 2004). Chert is largely made up of brown to orange, red, and grey to black color color categories. Clear and brown to orange chalcedony as well as dark grey quartzite have also been identified at Dollar Mountain. Phosphoria and Goose Egg Formations are known to be composed of chert and chalcedony, though a specific source has not been identified it is likely

Table 3: Known Source Locations		
Source	**Material**	**Locality**
Obsidian Cliff	Obsidian	Non-local, Greater Yellowstone area (GYA)
Laval Creek Tuff	Obsidian	Non-local, GYA
Cougar Pass	Obsidian (low quality)	Non-Local, South Absaroka Mnts
Dollar Mountain	Chert (orange-brown, red, grey-black)	Non-Local, South Absaroka Mnts
Dollar Mountain	Chalcedony (Clear, orange-brown)	Non-Local, South Absaroka Mnts
Dollar Mountain	Quartzite (dark grey, semi-opaque)	Non-Local, South Absaroka Mnts
Steamboat Mountain	Chalcedony (Clear)	Non-Local, Greater Green River Basin
Morrison Formation	Quartzite (Fine-grain)	Non-Local, Outcrops on margins of Big Horn Basin
Phosphoria & Goose Egg Formations	Chert (grey-white)	Outcroppings throughout GYA, and Bighorn and Pryor Mountains
Bridger Formation	Chalcedony (clear)	Non-Local, Outcrops in Greater Green River Basin
Irish Rock	Chert (Green)	Non-Local, South Absaroka Mnts
Irish Rock	Chalcedony (Green)	Non-Local, South Absaroka Mnts
48PA551	Limestone	Local, cliffs above site
48PA551	Conglomerate	Local, common material
48PA551	Sandstone	Local, common material
Dead Indian Creek	Basalt	Local, found in local streambeds
Dead Indian Creek	Quartzite (coarse-grain	Local, found in local streambeds

that outcrops are dispersed throughout the region, best known from the Bighorn and Pryor mountain ranges (Frazier and Schwimmer 1987). Clear chalcedony has also been identified in the Bridger Formation in southwest Wyoming and in streambeds on the western border of the Big Horn Basin (Wilson 1965). Opaque to translucent green chert is believed to be the unique materials acquired from Irish Rock (Bohn, 2007; Burnett 2005). These sources are best characterized by the study's identified materials green chert and green chalcedony. Purple-maroon chert, marbled chert, and marbled chalcedony have not been associated with a source. Identifying chert and chalcedony material variation is important but very difficult to do accurately (Church 1990). Though there is a like-ness between materials found at site 48PA551 and known sources in the region, source attribution of many material types is not accurate and are better used as guides rather than definitive guides. Figure 7 shows a map of the discussed source location in western Wyoming.

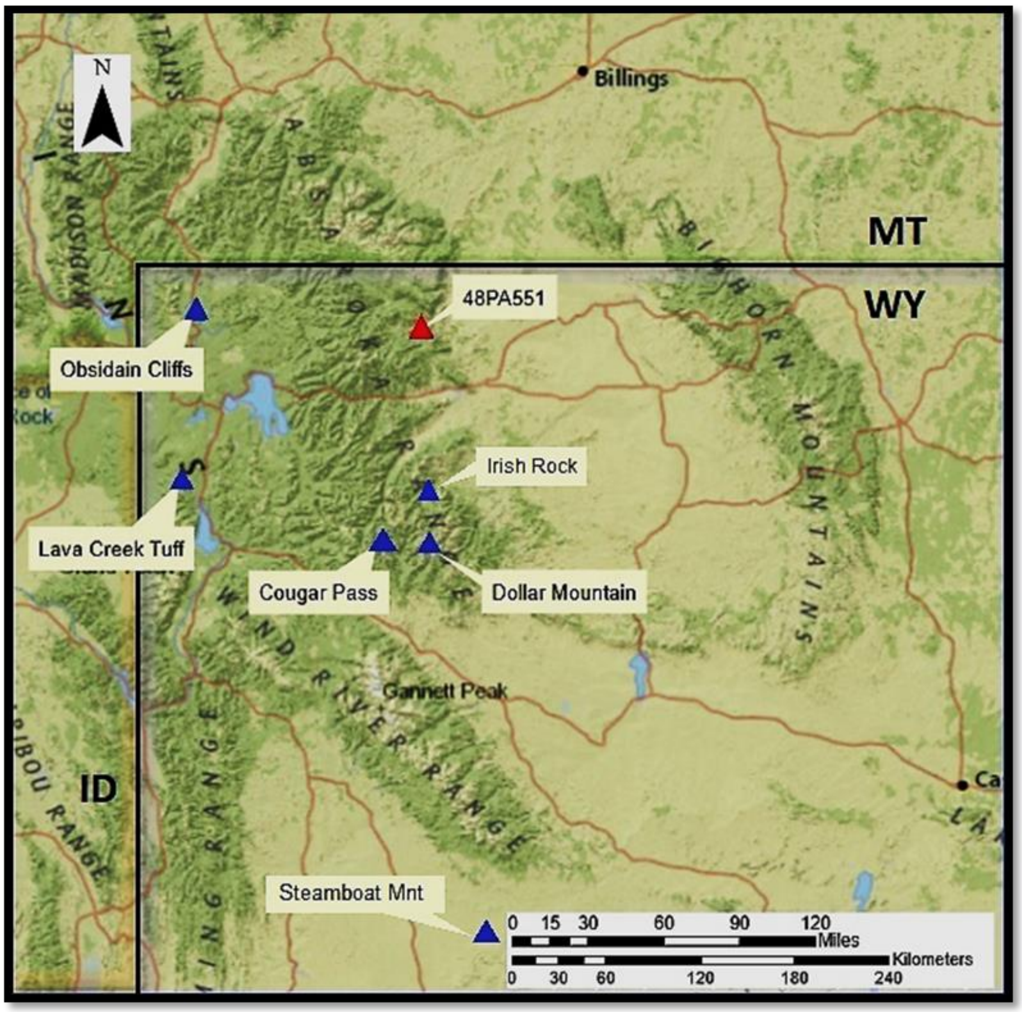

Figure 7. Map of Source Locations.

Figure 8 shows the general distribution of raw material types within the debitage assemblage. The assemblage is largely dominated by chalcedony at 40.5%, followed by chert at 28.2%. The “other” category makes up the smallest class at only 74 flakes and consists of a few

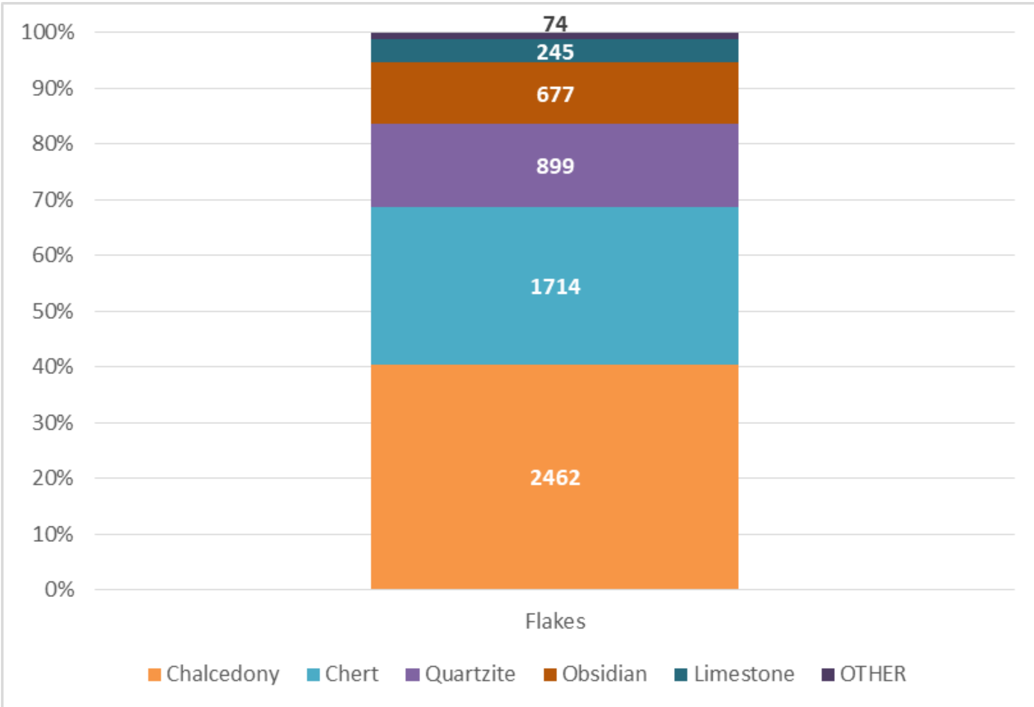

Figure 8. Distribution of Debitage by Raw Material

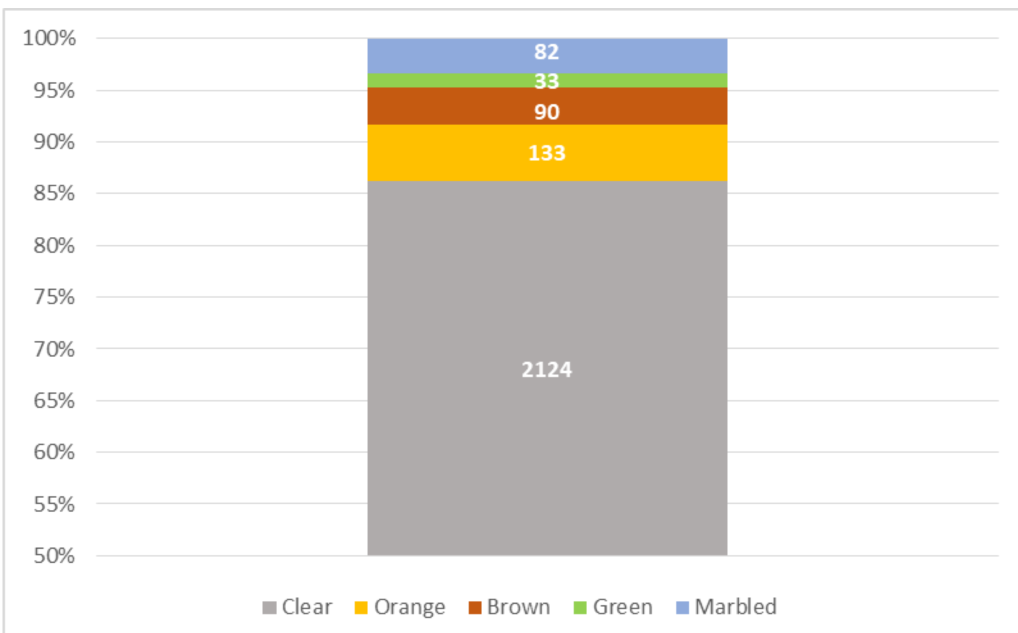

Figure 9. Distribution of Debitage by Chalcedony Material Variations

raw material types; petrified wood, sandstone, conglomerate, and basalt. Figure 9 goes into detail of the chalcedony flake distribution, subdividing the material by the characteristic of color. Of the five identified variations, clear chalcedony makes up a vast majority of the flakes made of this material type at 86.3%. Thus, clear chalcedony makes up 35% of the overall debitage, making it the most common material uncovered during the 2018 field season. Figure 10 shows a more even representation of the chert variations. Nine separate color classes of chert were identified during the analysis. The quartzite subdivisions include Morrison Formation (or fine-grain) and coarse-grain material. Figure 11 shows that fine-grain quartzite makes up a large majority at 80%. Three variations of obsidian were also identified during analysis (black, red, and banded) but have been analyzed as a single material type in this study due to the very low representation and lack of diagnostic attributes of the red and banded variations.

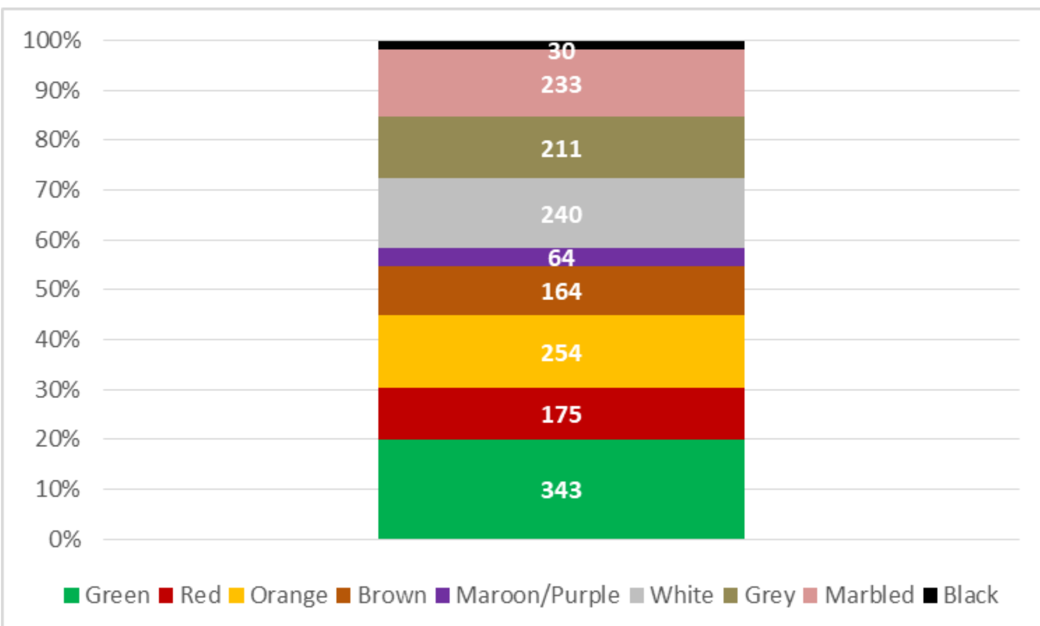

Figure 10. Distribution of Debitage by Chert Material Variations

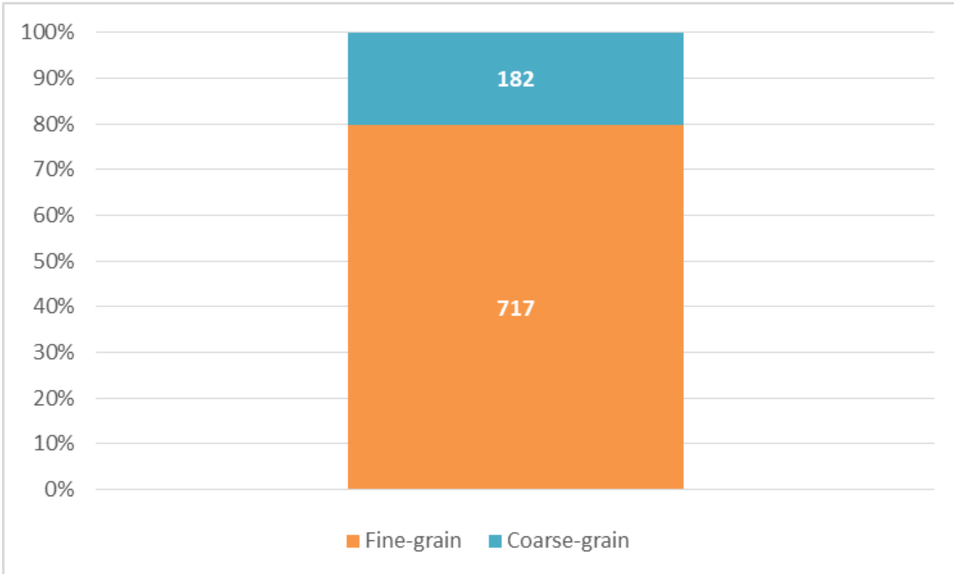

Figure 11. Distribution of Debitage by Quartzite Material Variations opposite

In the rest of this analysis chalcedony and chert will be grouped based on characteristics represenetive of known source location. Clear, brown, and orange chalcedony will be categorized as Dollar Mountain chalcedony. Red, orange, brown, grey, and black chert will make up the Dollar Mountain chert category. Phosphoria chert is made up of white chert, Irish Rock includes green chert and chalcedony, and the unidentified source materials will be analyzed seperately including purple and marbled chert, and marbled chalcedony. These unidentified source materials could be Morrison or Madison formation chert, but without more detailed petrographic studies it is difficult to know for certain.

This study continued the debitage analysis using Flenniken's stages of reduction (2001). Table 2 is a compilation of information from Flenniken's report indicating the flake types and diagnostic attributes for each stage (2001). Every flake was investigated and placed into a stage based on the attributes expressed. Flakes with medial-distal or non-orientable classification and tertiary cortex coverage were excluded from stage classification due to lack of diagnostic attributes. Unfortunately, undiagnostic flakes consist of about 76% of the assemblage. Investigating the relationship between flake stage classification and raw material type is valuable to determine the level of processing that occurred at the central place, site 48PA551. As stated in the first hypothesis, if a hunter-gatherer made the decision to partake in field processing, evidence of early stage reduction would not be present at the central place. Early stage reduction evidence includes larger flake size, presence of cortex, and wedge fracture initiation. Table 4 allows for analysis of the relationship between the material type and reduction stage of each flake, showing both count and distribution of flakes separated by material type. Through this analysis a few technological behavior patterns emerge.

Table 4: Stage of Reduction Representation by Material Type

	Limestone	Petrified Wood	Sandstone	Conglomerate	Obsidian	Quartzite	Basalt	Chalcedony	Chert
Stage 1	8 (42%)	1 (100%)	4 (100%)	6 (100%)	5 (4%)	13 (5%)	2 (15%)	167 (30%)	33 (7%)
Stage 2	3 (16)	0	0	0	7 (6)	23 (9)	3 (23)	48 (9)	62 (13)
Stage 3	6 (32)	0	0	0	9 (8)	21 (9)	4 (31)	34 (6)	70 (15)
Stage 4	2 (10)	0	0	0	92 (81)	188 (77)	4 (31)	312 (55)	313 (65)
Unknown	226	11	8	9	564	654	22	1901	1236

Obsidian, quartzite, basalt, and chert present a flake distribution as expected for materials that have been processed in the field. A very small percentage of flakes have early stage reduction characteristics represented by stage 1. A larger percentage occur in stages 2 and 3, but the largest amount of flakes are designated as stage 4, late stage reduction flakes. Chalcedony flake interestingly show a different pattern. The stage 1 flakes outnumbered the stage 2 and 3 flakes combined though was still proportionally smaller than the stage 4 flakes. This could potentially indicate a different behavior associated to this material type.

The remaining material in Table 4 generally show a greater percentage of flakes distributed into stage 1. In the case of petrified wood, sandstone, and conglomerate material, all of the diagnostic flakes are sorted into stage 1. Limestone flakes show a patterns of greatest representation within stage 1 and lowest in stage 2. The flake assemblage from these material types are shown to have characteristics most similar to early stage reduction, suggesting that hunter-gatherers did not make the decision to field process when transporting. This leads to the expectation that these material procurement sites were located closer to the central place.

With an in depth look at the material separated by source locations we see that Table 5 shows little variance in patterns between Morrison Formation quartzite versus the locally acquired coarse-grain material. Table 6 shows that most of the material groups follow a pattern as would be expected from material that was subject to field processing. However, chalcedony with characteristics of the Dollar Mountain source and white chert with characteristics of the Phosphoria Formation material show a pattern not expected by the first hypothesis, and do not a indicate presence or absence of field processing. This suggests that other cultural processes were acting upon the acquisition and use of these material types.

Table 5: Quartzite Distribution		
	Morrison Formation	Local Coarse-grain
Stage 1	12 (6%)	1 (2%)
Stage 2	20 (10)	3 (6)
Stage 3	19 (10)	2 (4)
Stage 4	142 (74)	46 (88)
Unknown	524	130

Table 6: Chert and Chalcedony Source Distribution							
	Dollar Chalcedony	Dollar Chert	Phosphoria Chert	Irish Rock	Purple Chert	Marbled Chalcedony	Marbled Chert
Stage 1	166 (31%)	16 (6%)	8 (22%)	2 (2%)	1 (4%)	1 (7%)	6 (12%)
Stage 2	46 (9)	40 (16)	2 (6)	11 (9)	2 (8)	0	9 (17)
Stage 3	33 (6)	39 (15)	4 (11)	18 (14)	3 (12)	1 (7)	6 (12)
Stage 4	287 (54)	159 (63)	22 (61)	95 (75)	19 (76)	12 (86)	31 (60)
Unknown	1815	580	204	250	39	68	181

Tool Analysis

The tools identified in this study were separated and then analyzed based on a number of characteristics; raw material, thermal alteration, size, number of EUs, retouch, use-wear, and edge angle. A tool typology was compiled specifically for site 48PA551. Tool analyses were checked for consistency and accuracy by Dr. Anna Prentiss and then recorded in a tool database. As with the debitage, this study strives to identify the relationship between technological behavior and raw material type. The following figures illustrate variation in the lithic tool assemblage by material type and compares evidence to the results of the debitage analysis in an attempt to identify economical decision making and behavior.

Figure 12 shows the number of tools in each category; core, formal biface, formal uniface, and expedient. Formal bifaces make up a large majority of the assemblage and include tools like biface fragments, projectile points, and bifacial knives. About 7% of the assemblage is made up of expedient tools like used flakes. Figure 13 goes into greater detail by showing the distribution of tools by general raw material types. Chert is the most common material type in the tool assemblage with the highest percentage of formal tools by a large margin. The flake assemblage is largely dominated by chalcedony and chert and the remaining material types only share approximately 30% of the assemblage. Expedient tools are uncommon in this assemblage and are distributed among many of the general raw material classes. A greater percentage of expedient tools in an assemblage is an indicator of a source site being close to the central place, but is not the case here. Figure 14 shows the tool assemblage related to the chalcedony and chert source variations. The Dollar Mountain materials are the only expedient materials within the chalcedony and chert variations though they also have the largest amounts of formal tools. Phosphoria chert also has a large number of formal tools with a single core. They also have a large number of cores with Dollar Mountain chalcedony with three. A separate graph was not compiled for quartzite variations because every quartzite tool uncovered was made from the Morrison Formation fine-grain material.

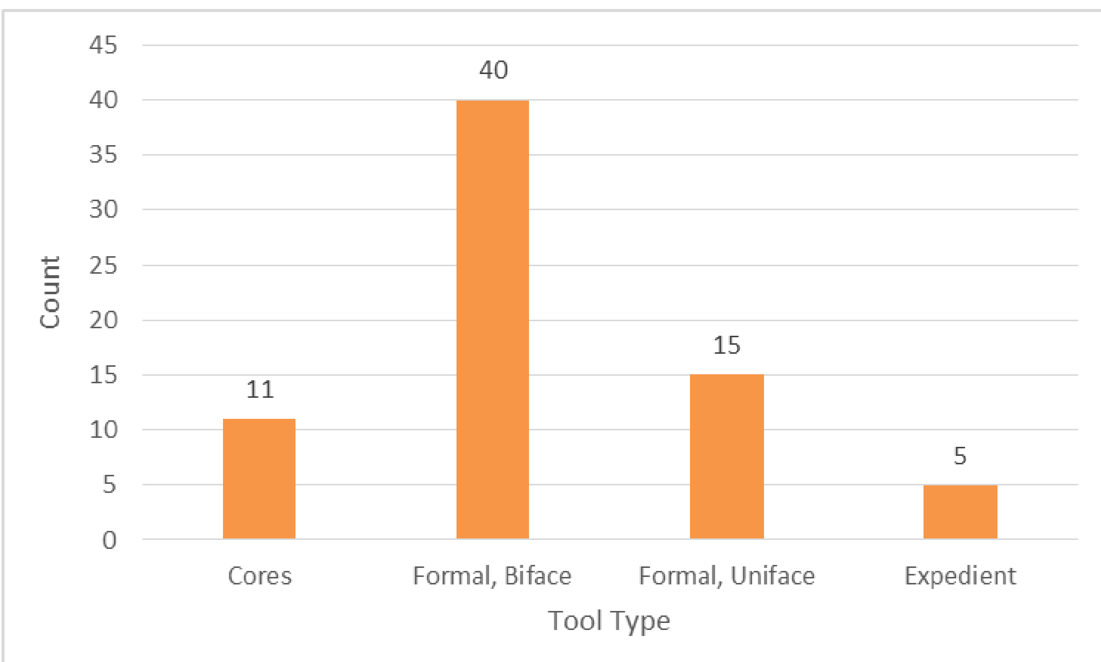

Figure 12. Tool Count by Technology Type.

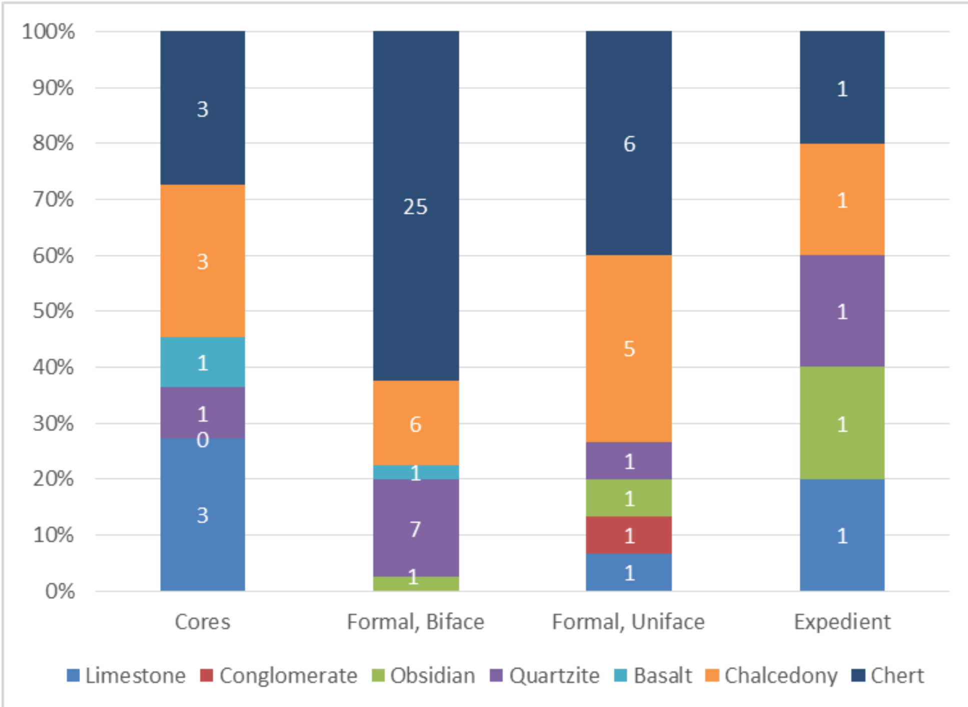

Figure 13.Distribution of Tool Technological Types by Raw Material Type.

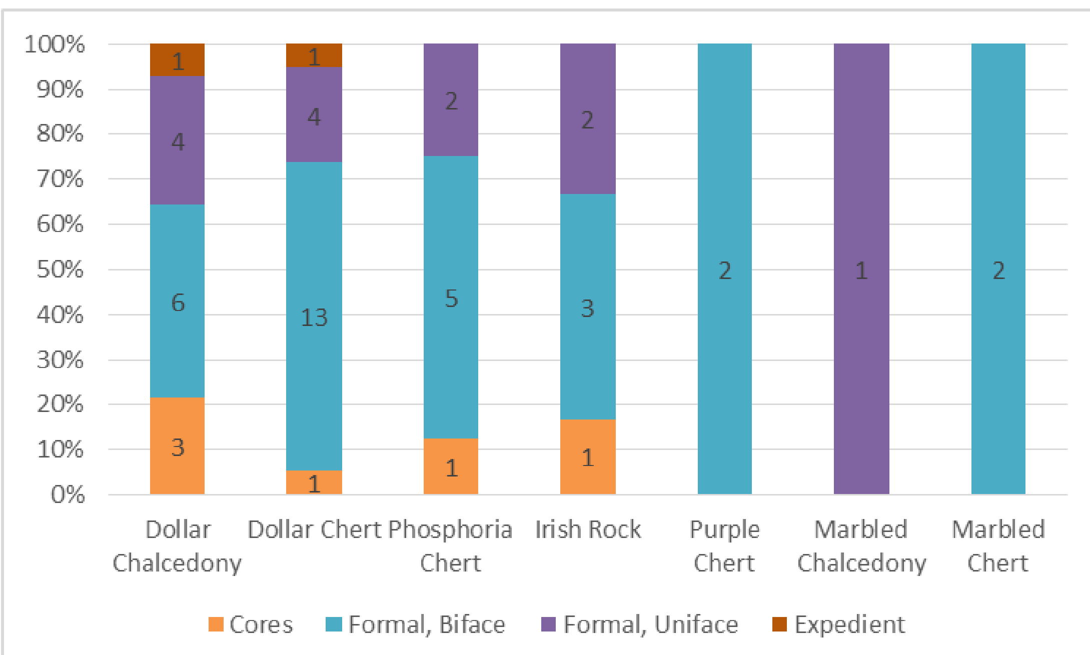

Figure 14. Distribution of Tool Technological Types by Possible Material Source.

The number of EUs on a tool is indicative of the amount of reuse and recycling in tools. Manufacturing a multi-tool would be essential for hunter-gatherers with the goal of extending the use life of valued material, especially if the material is procured a far distance away from their central place. Through analysis it was found that the site 48PA551 assemblage has tools with up to three separate EUs (see Figure 15). Cores were removed from this examination because they are tools without EUs. Of the 58 remaining chipped tools, 40% have a single EU. Limestone and conglomerate tools are found to only be made into tools with a single EU, making them the least invested in material by this measure. Quartzite, chalcedony, and chert are the only materials that are used to make multi-tools with up to three EUs. Figure 16 looks closer at the relationship between number of EUs and variations of chalcedony and chert. The Dollar Mountain materials also show variance from the other materials in this analysis because they have the most tools with 3 EUs and also have some of the largest distributions of 1 EU technology. Upon further investigation EUs within this assemblage are more indicative of the type of tool being investigated rather than evidence of recycling and reuse of material. For example, projectile points and fragments tend to have 2 or more EUs, but they are all associated to the same use not because they were recycled. In the discussion EUs will be investigated further to insure they are due to multi-tool use.

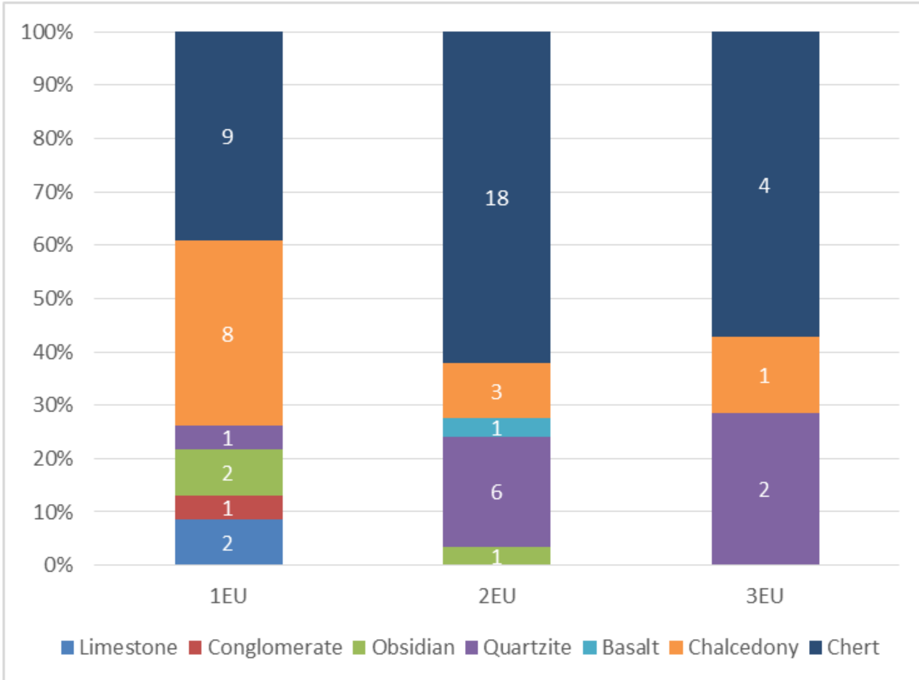

Figure 16. Distribution of Tool EU Count by Raw Material Type.

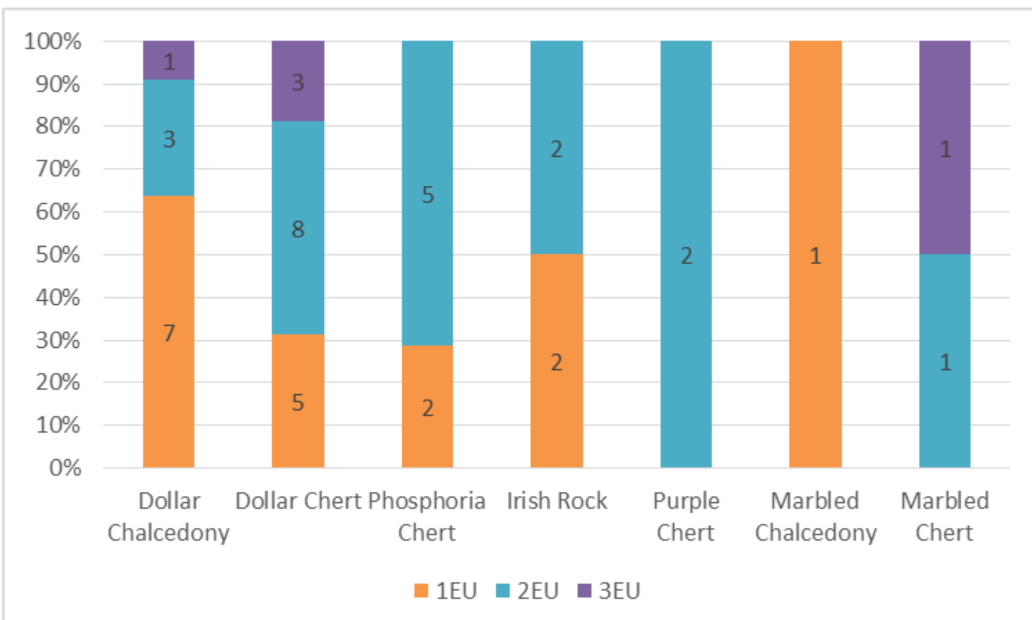

Figure 15. Distribution of Tool EU Count by Possible Material Source.

Tool size and thickness are also characteristics which indicating tool retouch and maintenance. As a tool is sharpened the margins are removed reducing the surface area of the tool while thickness largely remains the same. Therefore, when investigating the surface area to thickness relationship, tools with a larger than average ratio are more likely to have been retouched. During the analysis of this assemblage it was found that most tools were very small in surface area with a vast majority under 500 mm^2 (see Figure 17). The largest tools were made from conglomerate material, chalcedony, and limestone. The ratio of surface area to thickness is shown in Figure 18. The tools, represented by red points are being shown compared to the average thickness to surface area ratio and the standard deviation for each material type. Using this chart it is apparent that chert and chalcedony tools vary the most but also provide the tools with the greatest ratios. Conglomerate material and limestone tools have a visibly smaller ratio showing that despite being some of the largest tools, maintenance was likely not performed at the same extent as other material types. Figure 19 shows the surface area and thickness of the sourced chalcedony and chert tools. The material is largely clustered under 600 mm^2 surface area and a thickness of 7 mm. The outliers include marbled chert, green chert, Dollar Mountain chert, and one Dollar Mountain Chalcedony. Figure 20, like Figure 18, shows the surface area to thickness ratios for each tool, represented by the red plots, compared to the average ratio and standard deviation for each material type. The largest outlier is a Dollar Mountain chert tool, but most of the material has a ratio under 0.04. Marbled chalcedony, purple chert, and marbled chert are the tools with the smallest ratios in this graph and has the least amount of variance, though it may be due to the low number of tools made from these material types.

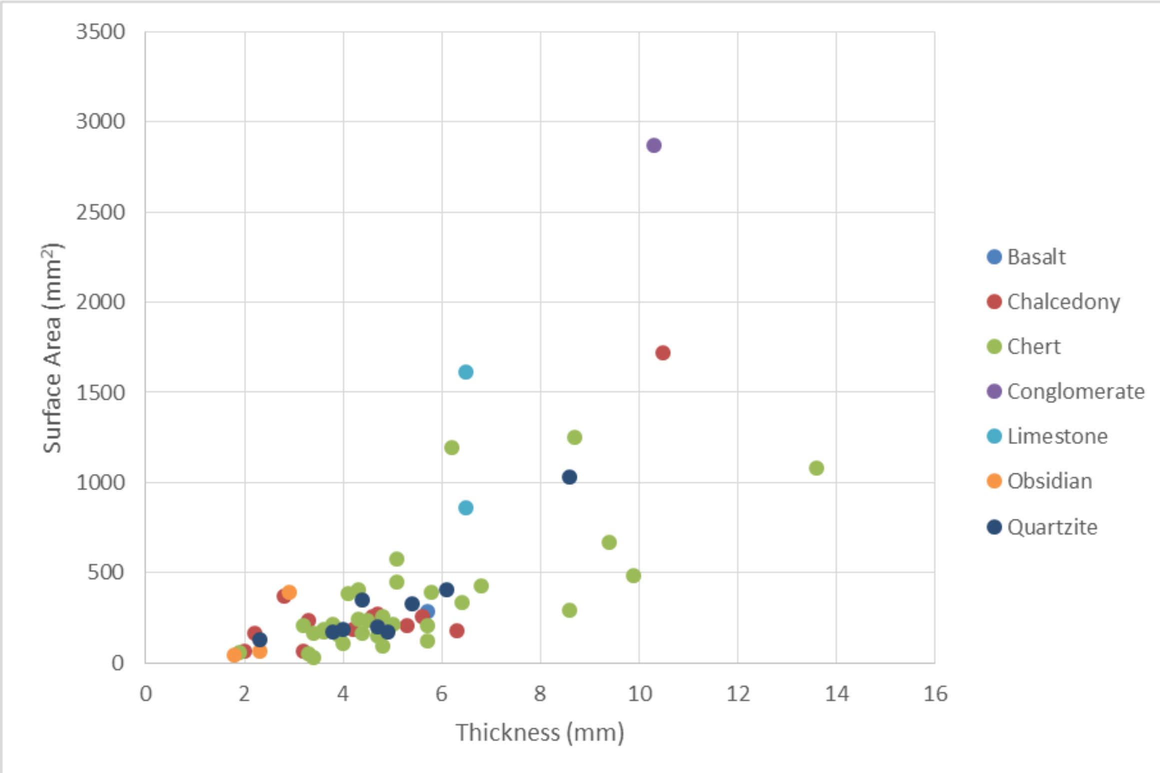

Figure 17. Tool Surface Area and Thickness by Material Type.

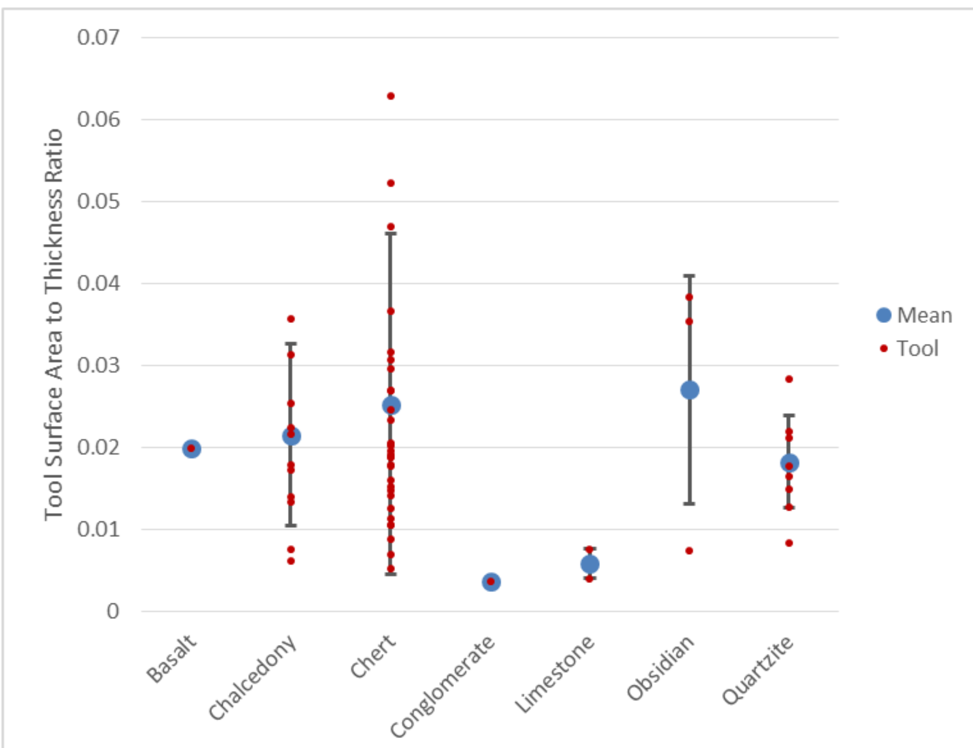

Figure 18. Tool Surface Area to Thickness Ratio, Showing Mean and Standard Deviation of Each Material Type.

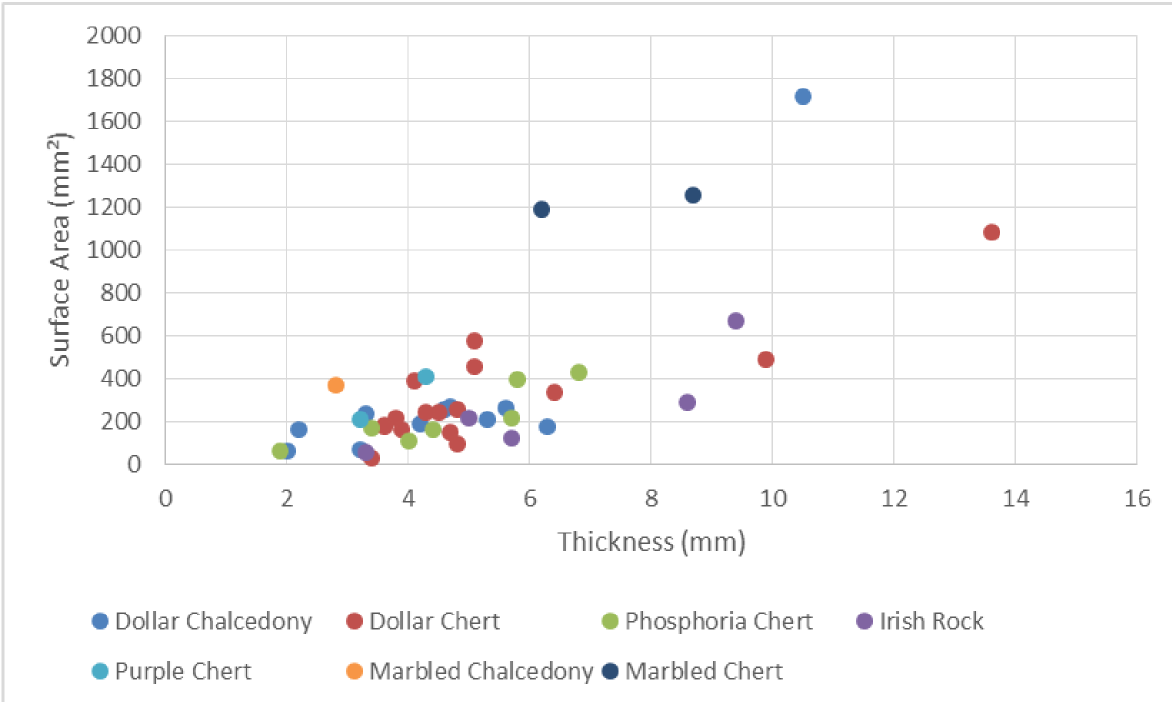

Figure 20. Tool Surface Area and Thickness by Possible Material Source.

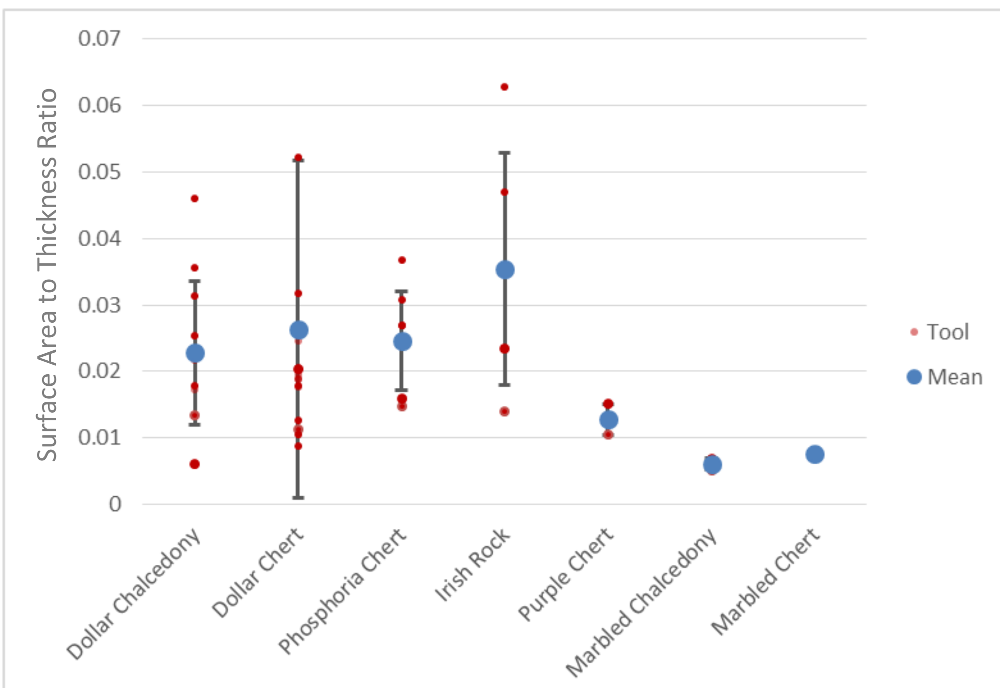

Figure 19. Tool Surface Area to Thickness Ratio, Showing Mean and Standard Deviation for Possible Material Sources.

Discussion

This study has focused its analysis of the lithic assemblage on evidence of hunter-gatherer behavior suggesting long distance raw material procurement and transport. As proposed by the study's hypotheses, a number of attributes have been identified as indicators of economical behaviors within the lithic assemblage. The hypotheses focus this analysis on both identifying evidence of the decision to field process in the debitage assemblage, and recognizing investment in extended material use-life in chipped lithic tools. The first hypothesis attributes the variation of debitage and tool data between material types to source location as predicted by the field processing model. The second hypothesis suggests that patterns will not arise as predicted, due to hunter-gatherers' involvement in other cultural processes other than economical decision making. The hypotheses were tested using the following methods.

As stated previously, every individual flake was assigned to a stage of reduction according to Flenniken's methods. This was done because different stages of reduction will be present in the debitage depending on whether or not field processing occurred. If the occupants of site 48PA551 chose to field process raw material while transporting to increase the utility of their load, evidence of early stage reduction will be absent from the central place archaeological record. The debitage of limestone, petrified wood, sandstone, and conglomerate material types are low in quantity but strongly suggest being locally sourced. The largest percentage of limestone flakes are from the first stage of reduction and thus indicate that attributes such as; presence of cortex, larger flake size, and wedge fracture initiation are more common. Because these attributes are frequently present, limestone was likely not field processed. This is consistent with the knowledge that the limestone was likely acquired from the cliffs above the site. The infrequency of diagnostic flakes for petrified wood, sandstone, and conglomerate materials make it difficult to confidently assert they were procured locally. However, of the diagnostic flakes identified, they exclusively fall within the first stage of reduction. This suggests that these materials were likely convenient but not favorable for making formal chipped tools. From what is known, conglomerate material and sandstone likely occurred naturally at the site. Sourcing petrified wood is more uncertain. It is believed that it was available at high altitudes within the Absaroka Mountains, but the distance from the central place is undetermined. It is likely that petrified wood was more easily accessible than most material types identified at the site, but was not found in the immediate vicinity of site 48PA551.

Basalt is also a material type with low flake representation within the assemblage. Contrasting from the other irregular types, basalt flakes show a different pattern. The basalt assemblage has a small amount of stage 1 flakes while each consecutive stage increases in size with the highest percentage of diagnostic flakes in stage 4 with 11.4%. This suggests that the basalt was field processed before transport. However, it was not as favorable as other material types. This is interesting because basalt has been identified in many streambeds throughout the region and due to the sites association to the Dead Indian Creek, basalt would more be more likely to show signs of early stage reduction within the assemblage.

With less than 1% of early stage reduction flakes and a significant increase in flakes sorted into stage 4, the data strongly suggest that obsidian was field processed. This coincides with the findings of research by Todd and Reckin (2019), which determined that over 90% of their obsidian sample from the site was acquired from the sources in the Yellowstone area.

Quartzite has been divided into two material variations, fine-grain and coarse-grain. Coarse-grain quartzite can be found in stream beds in the region. In the debitage analysis it is apparent that both variations of quartzite show the same patterning of field processed material with a low percentage of early stage reduction flakes and a large majority of flakes indicative of late stage reduction. Though these data support the idea that fine-grain quartzite was acquired from non-local Morrison Formation outcroppings, it does not correspond with known data for coarse-grain quartzite. Like basalt, this material has been identified in streambeds throughout the region. Perhaps Dead Indian Creek did not contain basalt or coarse-grain quartzite, or maybe there was better quality material located elsewhere.

Chert was broken down into nine separate material variations based on color. Chert occurs in a wide variety of colors largely dependent on mineral and organic inclusions. For example, red colored chert is the result of iron being involved during the formation process (Fischer and Knoll 2008). Chalcedony was divided into five variations, also separated by color. Clear chalcedony was the most frequently used material at site 48PA551. The varying colors suggest a diverse number of sources, although these locations are not definitive. Chert and chalcedony were investigated in this research by grouping the material variations into known source characteristic groups. For example, Dollar Mountain chalcedony has been known to vary in color from clear, to brown and orange. As shown on Table 6, it is apparent that *most* source groupings follow the pattern which suggests field processing has occurred, and therefore, procured from non-local sources. These variations show the smallest percentage of flakes in stage 1 with increased flake representation through to stage 4. White chert, possible acquired from Phosphoria Formation outcroppings, shows a different pattern. Material sharing characteristics with known Dollar Mountain chalcedony and Phosphoria Formation chert data vary because stage 1 contains a greater proportion of flakes than stages 2 and 3 combined, though stage 4 still hold the majority of diagnostic flakes. The processes contributing to this pattern are unclear and may be due to a different cultural practice taking place.

Supplementary to the debitage data, the stone tools were analyzed through evaluating the attributes identified in the first hypothesis; tool type, number of EUs, and surface area to thickness ratios. This information is valued on the basis that it would be more economical for a hunter-gatherer to invest in extending the use life of raw material procured non-locally. Therefore, if the debitage assemblage shows signs of field processing, the tool analysis should also largely reflect that behavior through evidence of investment in extending material use-life behaviors like recycling, reuse, and maintenance.

The limestone tool assemblage is made up of three cores, one expedient tool, and a unifacial single scraper. Limestone is one of the few material types made into expedient tools, a strong indicator of low investment in tool manufacture. Limestone tools also do not have more than one EU and show to be large compared to the average tool size (see Figure 15 and 17). The surface area to thickness ratio figure also shows limestone tools to have some of the smallest ratios in the entire assemblage (Figure 18). This evidence points to lack of investment in extending the use-life of limestone. It is likely that the occupants of the area did not find tool maintenance a valuable use of energy or time when this material was so easily accessible.

Only one chipped conglomerate tool was uncovered during the 2018 field season, a unifacial single scraper. Conglomerate material was much more likely to be used for groundstone tools in this site's lithic assemblage. This may be because it is not the most ideal material for flint knapping and does not typically produce a fine working edge like other more fine-grain materials. The single scraper has only one EU. It was also the tool with the greatest surface area at approximately 2900 mm^2 and the smallest surface area to thickness ratio. Little investment was placed in this tool to extend its use-life suggesting it was easily accessible. Basalt tools were also very infrequent in this assemblage with one core and one projectile point. The one flaked tool is a fragment of a Hanna projectile point damaged during production, indicated by its lack of use-wear. Even though the tool has two EUs, both are associated to the same point. There was no attempt to salvage the material after it broke. The basalt tool is very small in size, and has an average thickness to surface area ratio suggesting that the tool had been moderately retouched. The tool data for basalt suggests that the people invested in the material because of its use to manufacture a formal biface. However, the material type is infrequently used at this site and it is difficult to ascertain if the level of investment represents this single tool, or the use of basalt as a whole.

Despite the fact that the obsidian debitage assemblage is much larger than previously discussed material types, very few obsidian tools were uncovered during the 2018 field season. The obsidian tool assemblage consists of one expedient tool, one unifacial knife, and a fragment of a projectile point. Interestingly, the most EUs were discovered to come from the used flake. The used flake is a multi-tool and expresses use-wear and retouch. The obsidian tools do make up some of the smallest within the assemblage, as well as have an above average surface area to thickness ratio. The obsidian tool assemblage shows signs of material investment because of its use to make formal tools, its smaller tool size, and most tools have above average surface area to thickness ratios. This suggests that investment in obsidian was made to extend the use-life of the material after it was transported from a non-local source.

Morrison Formation quartzite was more commonly used to make formal tools. The assemblage consists of one core, one unifacial denticulate, an expedient tool, and seven bifaces made up entirely of projectile points and fragments. This large investment in manufacturing formal tools with quartzite suggests that it was a favored material for the occupants of site 48PA551, one expedient tool was made with material but 90% of its assemblage is still made up of formal tools. The quartzite was shown to have a large percentage of tools with two and three EUs, though this is due to the types of tools constructed, not because of tool recycling. According to Table 17, fine-grain quartzite tools largely cluster with a surface area under the average of 500mm^2, excluding the unifacial denticulate. Generally, the tools are relatively average in their surface area to thickness ratio with approximately half falling below the average of 0.02. It is unclear from analysis of these characteristics if fine-grain quartzite was a material worth investing in. This is because only half of the attributes suggests that the tool manufacturers extended the use-life by making formal tools and practice heavy retouch. Based on these data alone, it is impossible to determine if tool investment of this material type was an intentional economic decision.

Chert is the most frequently used material type in the tool assemblage and includes three cores, six unifaces, one expedient tool, and 25 formal bifaces. The bifaces largely consist of projectile points and biface fragments. When analyzing this collection of material a few things became apparent. EUs are not useful in indicating level of recycling and multi-tool status because projectile points and other bifacial tools frequently have more than one EU in this assemblage. Counting EUs is most useful when describing unifacial and expedient tools because they frequently only have one for each tool type. More than one EU would be uncommon and indicate tool recycling. It was also found that chert tools were very small on average with a majority of chert tools with a surface area below 500 mm^2. Regarding to the thickness to surface area ratio, the average for the tool assemblage is 0.02, while the average for the chert tool assemblage is greater at approximately 0.025. Based on this information, the chert material category largely shows investment in extending the material use-life suggesting that they were subject to field processing. However, there are few deviations from the overall pattern. The only expedient tool was made from Dollar Mountain chert. Although this is a characteristic of low material investment, this same used flake has two separate EUs, indicating that it was used multiple times. A green end scraper with characteristics of Irish Rock chert also was given two distinct EUs. As previously stated, a large majority of the chert tools were small in size. One Irish Rock, two Dollar Mountain, and the two marbled chert tools were larger than 500 mm^2. The purple and the marbled chert tools both had the fewest tools represented but they also had all very low ratios compared to the other chert tools suggesting little investment in retouch. Purple chert, similarly to the Morrison Formation quartzite, cannot be categorized either way. Marbled chert, on the other hand shows signs of little material investment.

Like the chert source groups, the chalcedony was mostly used to make formal tools. Dollar Mountain-like chalcedony is the most common variation. The lack of EUs per tool suggests that little investment was put into recycling tools made from this material type. The Dollar Mountain chalcedony tools are mostly small in size and the thickness to surface area ratios are highly variable. This evidence indicates that it is not possible to determine the level of investment in this variation of chalcedony based on these attributes. The representation of marbled chalcedony is very low. The tool is very small suggesting it was heavily retouched. In terms of the thickness to surface area ratio, marbled chalcedony is very low. This evidence indicates that while marbled chalcedony does not show signs of material investment.

The goal of this study was to reveal patterns indicating lithic technological behavior and make predictions of source locations using the central place foraging theory, the field processing model, and HBE. Evidence of field processing was observed in the data analysis for the many material types including; basalt, obsidian, Morrison Formation quartzite, coarse-grain quartzite, marbled chalcedony, and most chert material variations. Signs of field processing were not visible in the limestone, petrified wood, sandstone, and conglomerate material groups. Finally, Phosphoria Formation chert and Dollar Mountain chalcedony could not be determined either way. It is possible that other cultural or natural processes occurred to cause variation within the assemblage and not show the predicted result as determined by the first hypothesis.

The tool assemblage was analyzed for a number of attributes; tool formality, number of EUs, tool size, and surface area to thickness ratio. Each material assemblage was assessed based on these attributes to determine if they show signs of investment in extending the material use-life. The extension of material use-life is believed to be the goal of people who want to optimize the stone when transported over long distances, thus the same material subjected to field processing. Tool assemblages which communicated use-life investment include basalt, obsidian, Dollar Mountain chert, Irish Rock chert, and Phosphoria Formation chert. Limestone, conglomerate material, marbled chert, marbled chalcedony, and Dollar

Mountain chalcedony show more signs of no investment in material use-life. Fine-grain quartzite and purple chert do not exclusively belong to either category based on the tool data analysis.

This study's first hypothesis asserts that hunter-gatherers who occupied site 48PA551 during the Middle Archaic practiced economic rationality, specifically related to the accusation and transport of lithic raw materials. With the help of the field processing model, the lithic assemblage uncovered at the site has been analyzed to determine if the practice of economic rationality is visible in the archaeological record. The outcome of the debitage stage reduction analysis should be supported by the tool material investment data. This information is reflected in the debitage and tool data which suggest that if the material was locally sourced, it did not undergo field processing. Petrified wood and sandstone tools were not uncovered during the 2018 field season and very few flakes were identified. However, the flakes that were analyzed were early stage reduction flakes. Conglomerate stone was also not a very commonly flaked material, though was found to be popular for use in groundstone tools. The debitage and tool data suggested that conglomerate material was not field processed. Because it is known that sandstone and conglomerate material is available at site 48PA551, the evidence found in this study is largely reflective of the easy access of low valued chipping material. Though the source for petrified wood is unknown, this research suggests that it is also an easily accessible material.

Basalt also had a small assemblage of debitage and tools, but showed evidence of field processing. This knowledge it is reinforced by the debitage and tool analysis, which both determined that the material shows signs of field processing and tool material investment.

Quartzite was separated into two variations, fine-grain Morrison Formation and coarse-grain. Coarse-grain quartzite debitage did indicate field processing, though no tools were located during the 2018 field season. Interestingly, both basalt and coarse-grain quartzite are known to occur in streambeds throughout the region and are thought to exist in the Dead Indian Creek. However, because both materials show evidence of field processing and tool use-life investment strategies it may be possible that the Dead Indian Creek did not have this material or it was of poor quality. This study suggests reevaluation of these source locations. Fine-grain Morrison Formation quartzite debitage also indicates the occurrence of field processing due to the lack of early stage reduction flakes. The tools, on the other hand, do not support the claims made by the debitage data. The fine-grain quartzite tools show both presence and absence of material investment. Overall, these data suggest that Morrison Formation outcrops were a favored material for projectile points indicating that there could have been other material strategies occurring.

Of the identified chert variations, the data suggest many to be non-local material subjected to field processing through analysis of the debitage and tool assemblage. Dollar Mountain chert is known to be a non-local material and would show signs of field processing before transport to site 48PA551, as is reinforced by the data collected at site 48PA551. This research has also determined that the location of the green Irish Rock chert source would lead to the decision to field process and is supported by both the debitage and tool analysis. Purple chert was determined to be field processed based on the debitage, but the tool assemblage does not definitely suggest the presence of material investment. Marbled chert debitage is almost entirely made up of stage 4 reduction flakes suggesting field processing occurred, but the tool data show very little investment in extending tool use-life which contradicts the belief that raw material transported over long distances will be subjected to other optimal behaviors too. Lastly, Phosphoria chert shows a unique pattern of lithic assemblage behavior. The debitage does not follow a distinct pattern identified for field processing or not. However, the tool assemblage does suggest tool investment in extending the use-life. Although Phosphoria Formation chert is believed to exist in outcroppings throughout the Greater Yellowstone Area it is possible that the source for this material could be local or non-local leading to a different levels of field processing and material investment. It is more likely that the material is non-local and was subject to other cultural processes changing the pattern of material uncovered at site 48PA551.

The chalcedony assemblage is more complex than any other raw material type. Chalcedony with characteristics of Dollar Mountain material is the most prominent material type within the lithic assemblage. Unlike the Dollar Mountain chert, the chalcedony debitage data did not follow a pattern associated with the decision to field process or not, instead it more closely resembles that seen with the Phosphoria Formation chert. The tool assemblage on the other hand indicates that the material was not subjected to investment strategies like recycling, maintenance, and reuse. This suggests that either there was a different source of clear chalcedony, which makes up a large percentage of the Dollar Mountain assemblage, closer to site 48PA551 leading to the decision not to partake in field processing or economical rationality was not practiced associated to this material type and another cultural process was present. Through analysis of the debitage, marbled chalcedony showed to have a pattern indicative of field processing. However, the tool assemblage lacked signs of material investment causing contradicting results.

This study had mixed results. Numerous material types acted as expected according to the first hypotheses by showing economic decision making was made related to raw material procurement, transportation, and later tool use-life investment. These specific material types show that field processing and material use-life investment are behaviors dependent on procurement site distance from the central place. Although many material types support the first hypothesis, some material types do not fall neatly into one of the designated patterns. These materials, mostly made up of some chalcedony and chert variations, do not distinctively indicate optimal lithic technological behavior occurred and suggest other cultural processes influenced the assemblage as was proposed in the second hypothesis. Thus, this study proves both hypotheses are true dependent on the material type.

Limitations:

A number of limitations to this research were identified. The methods of the research could be found to cause some discrepancy due to the fact that it is largely a qualitative analysis. The Flenniken stages of reduction as well as the characteristics of material investment in the tools were determined using qualitative analysis with very little use of quantitative characteristics. This could lead to researcher error and could cause variance if the research was performed again with the same data. It is also possible the tool characteristics chosen to be investigated in this study were analyzed with the assumption that they were direct indicators of level of use-life investment, however it could be more descriptive of the assemblage and the preferences of the site occupants. As stated previously, this study chose to analyze the material types as if they were favored equally. This is problematic because material types were often preferred for different tool types. This could have impacted the analysis, especially that of the tool characteristics. This study also chose to group material based on known sources in the region. This could change the outcome of this research because it is very difficult to accurately source chert and chalcedony material based on visible characteristics such as color. In fact, it is likely that there is overlap between variations and different sources on the landscape because material of the same color or texture could be available at multiple different source locations. It is also likely that material was acquired from sources unknown to the researcher. With this in mind, organizing the data in this way was done to better understand the data and conclusions of definitive source locations were not made.

The Flenniken stages of reduction is one of many different methods used by archaeologists to attempt to identify reduction patterning within the archaeological record. Although these methods are useful in analyzing data, flakes types are not mutually exclusive to each reduction stage and this allows for error. Future research would benefit by trying other methods to establish consistency.

The nature of the lithic assemblage also presented some challenges. Firstly, the debitage assemblage is largely made up of undiagnostic flakes due to the fact that they lack cortex and evidence of fracture initiation. This could greatly influence which flake types are more likely to be uncovered at the site and could have the potential to change the outcome of this research. The assemblage analysis has also been limited to the lithic material uncovered during the 2018 field season. There is a possibility that the material uncovered in past excavations could either strengthen or change the conclusions found in this study.

Chapter 6: Conclusion

This final chapter delivers the final conclusions of this study with a brief discussion of the study. It ends with recommendations for future research.

This study of site 48PA551's lithic assemblage has begun the discussion of hunter-gatherer decision making within the Sunlight Basin and how this impacted their relationship with the landscape. By using HBE, central place foraging theory, and the field processing model patterns of lithic technological behavior were identified for a number of the raw material types at the site. Debitage was investigated for signs of field processing, and chipped stone tools were analyzed to identify investment in material use-life extension strategies. These behaviors are believed to be economic decisions related to the distance between the material's source location and the central place.

The data was analyzed in order to test the hypotheses. The first hypothesis asserts that the lithic assemblage is the outcome of optimal decision making which is motivated by the fact that people practice economic rationality. Hypothesis 2 alternatively states that people do not always make decisions based on economic rationality and in result the lithic assemblage will reflect other cultural processes. The study was tasked with identifying patterns attributed to material transport distance in order to test these hypotheses.

The results of this study have led to both hypotheses being accepted dependent on the material type. Limestone, petrified wood, sandstone, and conglomerate materials showed patterns consistent to the expectations of the first hypothesis showing a lack of field processing behavior and little tool use-life investment. Basalt, coarse-grain quartzite, obsidian, Dollar Mountain chert, and Irish Rock material types are also found to share this patterning by showing consistent evidence of field processing and high tool investment. The data for these material types show that people practiced economic rationality related to the lithic technology. The debitage assemblage reflects the decision of whether or not to partake in field processing and the tool assemblage corroborates with these findings by indicating the use of material investment practices if field processing was identified.

The second hypothesis was accepted for the following material types; Morrison Formation quartzite, purple chert, Phosphoria Formation chert, marbled chert, Dollar Mountain chalcedony, and marbled chalcedony. These material types either did not show consistency in findings between the debitage and the tool data, or the data were inconclusive. When debitage were determined to be inconclusive it was because a distinct pattern was not identified leading to the belief that another cultural processes was impacting the data. The tool data were inconclusive if it showed to have equal representation of investment characteristics and evidence of lack of investment. Many cultural influences could impact the results this way including practice of trade, belief in prestige and sacred material, and seasonal nomadic patterns. These behaviors cannot be measured with the parameters identified by this study.

There are a few opportunities to expand this research in the future. It is believed that the study could be expanded with the introduction of data collected during the early excavations at the site. By expanding the assemblage there is a possibility that patterning will become more distinct and the tool assemblage would be able to take a larger role in identifying technological behaviors. It would also be valuable to compare the results of site 48PA551 with those of other sites in the region. This data could also be used in the future to possibly identify unknown source locations. This would be increasingly valuable to determine the location of the chert and chalcedony sources and whether or not they are as distinct as is indicated by their color variations. It would also be interesting to establish if the field processing model is a valuable way to determine economic rationality within a lithic assemblage after definitively locating these sources. Continuing this research though better source mapping using GIS, as well as future excavations at the site could also lead to an improvement in the limitations discussed previously.

Overall, this study has taken the first steps to investigating site 48PA551 and the Sunlight Basin through the theoretical lens of human behavioral ecology and central place foraging theory. Reanalysis after incorporating past field season data and further excavation would be valuable, especially when investigating tool making strategies. In the end it is reasonable to state that the occupants of site 48PA551 were strongly involved with their landscape as indicated by their diverse raw material assemblage and economic strategies.

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